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REPORT

ON THE METEOROLOGICAL IMPLICATIONS

IN THE SELECTION OF THE DAY FOR

THE ALLIED INVASION OF FRANCE

JUNE 1944.

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Report on the Meteorological Implications
In the selection of the day for the Allied Invasion of France,
June, 1944

FOREWORD

1. The Report embodied in the following pages is an attempt to summarise some of the more important aspects of the manner in which meteorology, more particularly weather forecasting, was involved in the decisions which led up to the invasion of France on 6th June 1944 by the combined naval, air and army Forces of Great Britain and the United States. The operation was known by the codeword NEPTUNE and is referred to by this word in the Report.

2. While aiming at completeness the Report is intended to bring out only those aspects which are necessary adequate appreciation of the problems confronting the meteorological advisors of the Supreme Commander. In that the Report has been prepared in the Meteorological Section, Supreme Headquarters, without reference to the various meteorological Services which contributed so valuably to the forecasts used in the decisions, the views expressed are solely those of the SHAEF Meteorological Section.

3. Every effort has been made to do adequate justice to the contributions of each of the Forecasting Centrals, made during the course of the long and difficult series of conferences conducted by telephone by day and by night. Whatever procedure may be adopted for any similar operation in the future, it is unlikely that a greater degree of enthusiastic and helpful co-operation on the part of all the participants will be achieved.

4. A Report of this nature made primarily to be a record of the part played by organised meteorology in an important invasion operation, would normally end with a review of the military decisions as affected by weather forecasts. It has however, been considered that any value the Report may have, might be enhanced by summarising the experience of the Supreme Commander's meteorological advisors in a Section of "Comments and Recommendations". Such a Section has, therefore, been included.

5. All the purely technical discussions have been relegated to Appendices not because they are less important than any of the other sections, but because the Report is primarily a Report to the Supreme Commander and his Staff. The material in the Appendices is intended to provide information about the purely meteorological background for those readers who may wish to evaluate the contents of Section VI against the synoptic situation and developments during the most critical period.

SUPREME H.Q. OFFICIAL ALLIED EXPEDITIONARY FORCE

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22nd June, 1944

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Report on the Meteorological Implications in the Selection of the day for the Allied Invasion of France, June 1944.

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Report on the Meteorological implications in the selection of the day for the Allied Invasion of France, 1944.

I. Meteorological Requirements for the Various Phases of the Assault.

a. General Considerations

For such a complex operation as a landing on a heavily fortified coast, it is not an easy matter to determine one set of meteorological conditions which would be ideal from the points of view of all the arms concerned. The ideal conditions would change with the stage of the operation; in the hours immediately preceding and following the actual hour of first landing, the conditions would vary almost from hour to hour. Cloud conditions that would be most suitable for the landing of Airborne forces at HH-X hours would not necessarily be those that would give the heavy bombers their best opportunities at HH-Y hours; and those conditions in turn might not be necessary or even most advantageous for medium and light bombers at HH-Z hours; fighters might operate successfully under conditions different from those considered ideal for the troop carriers or for the heavy or medium bombers.

Probably the only firm prerequisite is the restriction on the strength (and in part on the direction) of the surface wind with its immediate effect on the state of the sea both for the crossing before the landings and its effect on the waves and surf on the landing beaches. But the wind at the time of crossing and at the time of landings is not the only factor affecting this aspect of the operation. If the sea and the beaches are open to the direction from which swell produced by high winds up to hundreds of miles away, is liable to come, then the force and direction of winds hundreds of miles away from the operational area have to be taken into account. And the local conditions of sea are affected by the strength, direction and duration of the local winds for a number of hours before the critical time, depending on the fetch of the particular coast.

Hence, from the viewpoint of naval operations alone, the ideal conditions would be little or no wind within the actual sphere of operations and no swell-producing wind for the whole period covering the time of sailing of the assault forces to their landings on the beaches.

Visibility, as affected vertically by cloud and horizontally on the surface by fog, mist/haze, is one of the most important factors for the Air and Naval aspects of the operation. Visibility must be good enough to let the various types of aircraft take off from, and assemble over, their bases and see their targets in and behind the assault area; visibility must be adequate at sea to allow the multitude of craft involved keep their proper station and also allow the naval bombarding forces see their targets on land in close bombardment; the aircraft spotting for the naval bombarding force must also have visibility adequate for directing the force on to its land or sea targets.

There are other factors; for example, the condition of the ground in the operational area as regards softness (mudiness) for the movement of heavy vehicles both tracked and untracked. This factor is taken account of in the planning stages but in certain circumstances may also be important in deciding the day of assault.

Of a more detailed character, but in certain contingencies by no means unimportant, are the actual conditions as regards vertical temperature structure in the atmosphere and wind speed and direction along the coast line immediately preceding, at, and following HH hour. These conditions determine the behavior of smoke screens.

b. Actual Limiting Conditions Used for the NEPTUNE Operation

In English weather, even English summer weather, it was clearly impracticable to set up an ideal set of conditions even if such were possible and defer the assault until this set of conditions was obtained. In the summers of some years they would never be obtained within any predetermined period of, say, a month or even two months. Besides, other factors quite apart from the purely military and political factors, are (unfortunately) at least as important in

determining the period within which the assault must be affected. These factors include the times of high and low tides and the intensity of ground illumination as affected by twilight and phase and altitude of the moon.

It was therefore necessary to define a set of minimum meteorological conditions which could be accepted by all arms as being the worst conditions in which the operation could be launched.

Such a set of minimum conditions were never wholly accepted by all the forces but the following represents the conditions which the Meteorological Section SHAEF kept in mind:

NAVAL Requirements.

(1) Surface winds should not exceed Force 3 (8-12 mph) on shore or Force 4 (13-18 mph) off shore in the assault area during the days D to D plus 2. Winds might be Force 5 in the open sea but only for limited periods.

(2) In the days preceding D-Day, there should be no prolonged periods of high winds of such direction and in such Atlantic areas as to produce any substantial swell in the Channel.

(3) Visibility, not less than 3 miles.

AIR FORCE Requirements.

(1) Airborne transport; (HH-6 to HH-4):

(a) Cloud ceiling at least 2500 feet along the route to and over the target area.

(b) Visibility at least 3 miles.

(2) Heavy Bombers (HH-4 to HH):

(a) Not more than 5/10 cloud cover below 5000 feet and cloud ceiling not lower than 11000 feet over the target area.

(3) Medium and Fighter Bombers (HH-2 onwards):

(a) Cloud ceiling not less than 4500 feet, visibility not less than 3 miles over the target area.

(4) Fighter and Fighter Bombers (HH-18 onwards):

(a) Cloud base not less than 1000 feet.

(5) Base areas:

(a) Cloud not below 1000 feet and visibility not below a mile except for heavy bombers for which there is the additional stipulation that low cloud tops must be less than 5000 feet high and there should be only fragmentary middle cloud.

ARMY Requirements.

(1) Airborne Troops Landings:

(a) For Paratroops, the surface-wind over the target area should not exceed 20 mph in the target area and should not be gusty; and for gliders the surface wind should not be over 30-35 mph.

(b) The intensity of the ground illumination should not be less than half moon at 30° altitude or the equivalent in diffuse twilight.

(2) Ground Forces:

The ground should be sufficiently dry to allow movement of heavy vehicles off made-up roads.

II. Summary of Results of Statistical Examination of the Probability of Obtaining Most of the Above Requirements on Any One Day or Sequence of Days.

In the months preceding the launching of operation NEPTUNE, examinations of weather statistics for past years were made from many different angles with a view to estimating the probability of obtaining specified weather conditions at various periods from April onwards. Some of the results obtained at various times, using different sets of basic information, were as follows:-

Defining a quiet day as one with wind less than Force 3 onshore and Force 4 offshore, on the Normandy Coast of France and stipulating the following overall requirements for the periods of the assault:

(a) D-Day be within the period of one day before to four days after new or full moon (that is assuming landing of Airborne troops could be affected irrespective of ground illumination from moon light)

(b) D-Day be itself quiet and followed by a sequence of three quiet days.

(c) Cloud less than 3/10 below 8000 feet and visibility more than 3 miles.

(d) Alternative to (c), cloud base generally above 3000 feet and with morning mist or fog not excluded.

The following arithmetical values were obtained for the probabilities of the various conditions (a), (b), (c) and (d) above:

		May	June	July
		Chances to 1 Against		
(1)	(a) (b) and (c) together	24	13	50
	(b) and (c) without (a)	9	4½	19
	(b) and (c) with (a) limited to full moon	49	24	100
(2)	(a) (b) and (d) together	11	6	16
	(b) and (d), without (a)	4	2	5
	(b) and (d) with (a) limited to full moon	24	13	33

Of these various sets of conditions, the third set in the second group was the most likely to have to be accepted, viz. D to D plus 3 quiet as regards wind, cloud base generally above 3000 feet and the conditions restricted in any one month to six days around full moon. Even with those conditions which did not cover the minimum requirements for some of the phases of the operations, the chances of obtaining the conditions together over a set of days were very low, viz. 24 to 1 against in May, 13 to 1 against in June and 33 to 1 in July. One important result did come out from these and many other exeminatios, viz. that June was likely to be the best of the three early summer months. So that if the operation was planned for May and postponed, June, with better chances, was still to come; but if the operation were planned for June and deferred, its chances of similar conditions in July (and subsequent months) would be less good than for May or June.

There were, of course, meteorological reasons for avoiding May for Channel operations if at all practicable; one of these was the statistical frequency of occurrence of winds from between northeast and east in the eastern and central Channel area. These winds coming over the water of the cool North Sea bring low stratus cloud liable to persist with 10/10 cover for days at a time in the central and eastern Channel area.

III. The procedure for achieving an agreed weather forecast for the NEPTUNE Operation.

As statistics from past years' weather were known to be quite an unreliable and unhelpful guide for the actual selection of D-Day, it was decided at a meeting of the Directors of the Meteorological Services concerned (Air Ministry, U.S. and Naval) in January 1944, that the utmost efforts should be directed to framing as a routine procedure each week, a forecast of weather conditions covering as long a period ahead as could be issued with substantial confidence: 5 days was the period aimed at.

It was arranged that regular conferences be held using scrambler telephone conference facilities and with the following participants:

Air Ministry Forecasting Central, Dunstable
U. S. Forecasting Central, Widewing
Naval Meteorological Forecasting Central, Admiralty

The Chief Meteorological Officer at SHAEF or his Deputy was to be the Chairman at each of the conferences which would include the Meteorological Staff Officer of the Naval Commander in Chief, and the Chief Meteorological Officer (or his Deputy) at the Headquarters, Allied Expeditionary Air Force.

The purpose of the conferences was to arrive at an agreed forecast for a period of 5 days; the advice to be submitted to the Supreme Commander and his Commanders-in-Chief would be based on this agreed forecast.

These conferences started in February 1944, at first on a two or three times a week basis; from the middle of April, the conferences were held each day.

Actually the need for daily conferences became necessary for at least two different reasons:

(1) In all but abnormally (for England) quiet conditions, the expert and experienced meteorologists at the participating Centrals seldom found it practicable to forecast with any useful confidence beyond 2 or 3 days; and

(2) The original intention of restricting the functions of the conferences to the framing of an agreed planning forecast developed into aiming at giving broad operational details for at least the first two or three days. Events soon showed that daily modification of the forecast was necessary to ensure that those details be operationally useful to the senior meteorological officers at the lower formations to which the agreed forecasts were distributed.

For large scale exercises and operations preceding the actual NEPTUNE assault (e.g. the FABIUS operation on 3rd May 1944), and more particularly as the scheduled day of the NEPTUNE operation approached, the number of conferences between the forecasting Centrals and the Meteorological Advisors to the Naval and Air C's-in-C was increased to three a day:

(1) A preliminary conference in the late afternoon (1730 h) to allow the Centrals to discuss the lines on which they were thinking about synoptic developments over the next five days.

(2) A main conference in the late evening (2100 h) at which the terms of a 5-day forecast (agreed or accepted by all concerned) were discussed. And

(3) A morning conference (varying in time from 0630 to 0830 h) at which any necessary modifications in the operational part of the previous evening's 5-day forecast were discussed and a modified forecast issued if required.

On the days immediately preceding D-Day, a further conference was held at 0300 each morning on which to base the final advice given to the Supreme Commander's meetings at 0415.

Each of the conferences usually lasted about one hour; they sometimes extended to two hours, particularly the evening conferences preceding D-Day.

IV. Forecasts of Weather suitable for Assault Operations, submitted during May, 1944, to Supreme Commander or his Staff:

With a view to testing the effectiveness of the information contained in the five-day forecasts prepared by the procedure outlined in the preceding section, the Meteorological Section, SHAEF, was instructed to submit each day those dates at least two days ahead when it was thought that conditions would fulfil most of the requirements referred to in Section I. In effect, each day more than two days ahead was to be considered as a possible D-Day, and the conditions on that day and on immediately preceding and succeeding days were to be considered in the light of their suitability for launching an assault. If the conditions were considered as likely to be suitable, the Assistant Chief of Staff, Plans and Operations (G-3) Division was informed.

From the early days of May, a total of eighteen dates (including the first two days of June) were submitted either separately or in sequences of two or more days, as days for which the weather was forecast at least two days in advance as being suitable for launching an attack on the selected coast of France.

Considering that the weather in May was mainly of a settled type, it was not surprising that the weather on these dates did in fact turn out to be substantially as forecast and suitable for launching a large scale assault.

V. Weather information and advice furnished to the Supreme Commander's Staff in the preparatory stages of Operation NEPTUNE (viz. on May 28th, 29th, 31st and June 1st.)

(1) In this period during which decisions had to be taken for the sailing of those assault and naval bombardment forces which were coming from a considerable distance, it was recognized that no definite forecast could be given for conditions on and immediately following the scheduled D-Day, 5th June.

(2) On Sunday, 28th May, the Supreme Commander was advised through the Assistant Chief of Staff, G-3 Division, SHAEF, that the evidence then was that mainly quiet wind conditions would continue during the week. Even in the present stable situation, nothing helpful could be said about wind or cloud conditions on D-Day but the risk of conditions changing so much from what they are now as to produce a gale in the Channel then seemed rather small.

(3) On Monday, 29th May, to a meeting at 1000 hours at Portsmouth, of the Supreme Commander, his Commanders-in-Chief, and their Chiefs of Staff, the following forecast was presented for the five days until Friday, 2nd June.

Mainly quiet wind conditions (not more than Force 4) throughout the period except for a wind of Force 5 in the extreme western Channel areas on Thursday and Friday.

Variable cloud conditions with an average of 5/10 to 7/10 except in local thunderstorms during the first two or three days; cloud would probably increase from the west at the end of the period. The visibility would be good except for morning coastal haze and in thundery showers.

The confidence was given as moderate for continuation of quiet wind conditions but low for details of cloudiness and developments toward Thursday and Friday.

In course of questioning at this meeting about conditions for Saturday, 3rd June, it was repeated that there was a risk of deterioration at that time especially as regards cloud conditions, but that the outlook was favorable from the viewpoint of wind in the Channel.

The basis of this advice was that there was no evidence to indicate that the existing northeasterly extension of the Azores high pressure area would be substantially modified in the next four or five days; it was therefore a reasonable expectation that, even if it did begin to recede or collapse at the end of that time, it would still influence the movements andintensities of any low pressure systems that might effect the operational area by giving them a northeasterly track away from the English Channel.

(4) <u>0830, Wednesday, 31 May</u>. The Assistant Chief of Staff, G-3, SHAEF, was advised that since Monday morning's conference at Portsmouth, the situation did not look as favorable as it then did for weather in the Channel area from Sunday, 4th June, onwards. But there was as yet no definite evidence that winds would be sutstantially above Force 4 for long periods; nothing helpful could be said at that stage about cloud conditions on June 4th and 5th.

This advice was based on the prognostic analyses agreed by the forecasting cetrals to the effect that there were indications that the Azores high pressure area was beginning to show signs of weakening, though there was time for a replacement high pressure area to move in or resuscitate it from the west.

(5) <u>0845, Thursday, 1st June</u>. The AC of S, G-3, (General Bull) was advised that there was no new evidence to change the forecast as give him yesterday (para.(4)). The balance ofevidence was that wind in the Channel area should continue not more than Force 4 over the weekend and on Monday, 5th June, but no forecast for cloud could be given. The confidence in operationally quiet wind conditios continuing into Monday was somewhat less than in the forecast given on Wednesday.

VI. <u>Summary of Meteorological statements made at the Supreme Commander's meeting at Portsmouth (Friday 2nd June to Monday 5th June)</u>.

In their essentials, the statements are reproduced in as nearly as practicable the same form of words as were used at the meetings.

<u>1000 Friday, 2nd June</u>.

Winds in the Channel and particularly in the Normandy area will probably be Westerly, mainly not above Force 4, but Force 5 at times particularly in the western channel towards the end of the period (Monday and Tuesday).

Cloud conditions on Sunday and Monday cannot be forecast with any degree of confidence; they will be variable. Amounts will be 7/10 to 10/10 in the early morning in the operational area, clearing partially in the forenoon to 5/10 or less but with patches up to 10/10 for considerable periods.

Visibility will be moderate to good generally but with risk of fog patches in the Channel and coastal areas on Monday morning.

The general type of weather is westerly in which Force 5 winds cannot be ignored at any time and in the warm humid air brought across the Atlantic from lower latitudes, cloud conditions are always uncertain particularly over higher ground in coastal areas and in the southwest of the Channel area.

There is now indication that the present relatively quiet weather may end about Tuesday.

2130 Friday 2nd June.

The general meteorological situation has not changed substantially and the forecast presented at the morning conference still stands. The flow of moist warm air over the operational areas will produce much low cloud. The whole development is at the moment sluggish and slow to show its hand; but, on the whole, the outlook for Sunday and Monday seems not unfavorable from the point of view of wind speed, namely, mainly Force 4; but there is a risk of Force 5 winds on Tuesday. The outlook for cloudiness is very uncertain; considerable periods of 10/10 cloud cover with base about 1000 feet must be expected. The times of these periods cannot be forecast accurately.

To a question (Supreme Commander) about conditions on Tuesday and Wednesday the reply was that the evidence at present did not indicate much difference on those days from the conditions as just described for Sunday or Monday; there was no basis for forecasting persistent high winds though there was a risk of Force 5 on Tuesday; cloud conditions would probably continue poor with periods of 10/10 at 1000 feet.

Another inquiry (D/Air C-in-C: Gen. Vandenburg) was directed to conditions for the transport and landing of Airborne troops overnight Sunday-Monday. The reply was that cloud base would probably be mainly above 1000 feet but there would be patches with base at or below 1000 feet after 0200 on Monday morning.

0800, Saturday, 3rd June.

AC of S, G-3 (Gen. Bull) was informed by telephone that there was no indication of improvement from the terms of the forecast presented at 2130 the previous evening. But the risk of Force 5 winds then forecast for Tuesday had now to be brought into Monday and even the latter part of Sunday. The view at the moment was that these Force 5's would be mainly on the English Channel coast

The cloud forecast is still very uncertain; the most likely cloud conditions are 7/10 to 10/10, base 1000 feet, especially in the early morning hours No opinion can be expressed about exact times of clearances, except for areas well inland during the afternoon.

General Vandenburg (D/Air C-in-C) and Admiral Creasy (C of S to Naval C-in-C) were given the same information. It was emphasized that the synoptic situation had become an extremely difficult one, and forecasts as to details were given with low confidence.

2130, Saturday, 3rd June. Supreme Commander's Meeting.

The high pressure area over the Azores is rapidly giving way and a series of depressions across the Atlantic is moving rapidly eastward; these depressions will produce disturbed conditions in the Channel and assault area.

Winds will be west-southwest, Force 5 on English Coast, Force 3-4 on the French Coasts from early Sunday, until a cold front trough passes. That passage is timed to be sometime on Wednesday, 7th June.

From Sunday morning onwards, cloud will probably be mainly 10/10 with base 500-1000 feet in the morning hours. This cloud may break in inland areas during the day and become about 5/10, but will continue of variable amounts in the Channel area and on both coasts with considerable patches of 10/10; its base will be at or below 1000 feet. The time of incidence and local distribution of these patches of low cloud cannot be forecast with confidence.

Some patches of medium and high cloud, mainly confined to South England must also be expected; amounts of this type of cloud will be less in areas well inland, e.g. over the Eastern Midlands and over the East Anglia bomber base areas.

Visibility will be mainly 3-4 miles, though 5-6 miles inland in the afternoon can be expected. There is a risk of fog spreading from the West up the Channel to sea and coastal areas. After Monday this risk of fog will decrease.

These details cover the period Sunday to Tuesday and at first on Wednesday, as far as can be seen with any confidence at the moment.

During Wednesday, a front associated with a depression now off Nova Scotia and the New England States will probably pass through the assault area.

Just preceding this front there will be a period of 10/10 multilayer cloud (low, medium and high); then as the front passes there will be a decrease of cloud amount and increase of cloud base heights, becoming 5/10 to 2500 feet. Visibility on Wednesday will be moderate at first becoming good after the front passes.

Further meteorological forecasts and statements made at this meeting were as follows:

(a) Air C-in-C, on a question about likely conditions for heavy bombers taking off from bases early on Monday morning:

10/10 stratus cloud, base 500-1000 feet and about 3000 feet thick; with a second layer of medium cloud base between 8000 feet and 12000 feet. This second upper layer will probably not be a continuous 10/10ths sheet.

(b) Air C-in-C, about conditions for enemy aircraft using their own bases:

Cloud along the French Coasts will probably be 10/10, base 500-1000 feet; but inland, away from the coastal strip, cloud amounts may be expected to be less during the middle part of the day.

Conditions over enemy bases on Monday will, on the whole, be better than over bases in England.

(c) Naval C-in-C, whether Force 5 winds along the English Channel are likely to continue through Monday and on Tuesday. Force 5 winds must be expected on Monday and on Tuesday.

(d) Naval C-in-C; would cloud conditions also be similar on Tuesday?

Similar cloud conditions will probably continue from about Sunday forenoon until Wednesday, when the clearing front is due to pass through the operational areas.
No useful forecast can be given beyond that at present.

(e) To a general question about probable weather conditions after Wednesday, the reply was that weather could not be expected to settle down quickly after the present very disturbed situation. But the prospects were, alternation of periods of greater and less cloudiness with mainly moderate westerly wind though fresh at times, associated with minor fronts and ridges of high pressure.

(f) The Supreme Commander commented on the slightly more optimistic note that he felt had come into the picture between the morning and evening conferences on Friday; and asked whether the forecast might not be more optimistic again tomorrow morning.

There is very little chance of any information being received before 0300 which is likely to give a more optimistic turn to the forecast. Since at least yesterday (Friday) morning, the whole meteorological situation has looked very unpropitious for a Monday assault but the outlook has been finely balanced, in that it might have swung to better or much worse. On Friday evening there was a very slight tip of the balance on the favorable side but the balance now has swung too far to the unfavorable side for it to be quickly counteracted.

The supreme Commander said that he had certainly been left on Friday morning with the impression that the situation was both difficult and uncertain.

(g) Deputy Supreme Commander asked whether the meteorological centrals were all agreed about the forecast as presented.

The centrals have agreed to accept the forecast.

(Following the presentation of this information, the assault was provisionally postponed for 24 hours.)

0415, Sunday, 4th June.

No new evidence has been received which allows any substantial change in the forecast presented last (Saturday) evening. The only small change is that the front, which was then expected to clear the Channel areas of low cloud on Wednesday, is now expected in the first part of Wednesday.

Winds will be Force 5 in the Channel from early Monday onwards, though somewhat less in sheltered areas on the French Coast.

10/10ths cloud, base 500-1000 feet are expected along the Channel area, with no forecastable difference in these conditions from Sunday to Tuesday.

The Naval C-in-C asked when these overcast skies would appear at Portsmouth, commenting that it was a practically clear sky with calm wind at the time of the meeting. He was advised that the cloud would increase during the early forenoon, of that day (Sunday).

(Following this presentation the time of the assault was deferred by 24 hours in the first instance.)

1745, Sunday, 4th June.

AC of S, G-3 was informed that there had been a substantial change in the situation since the early morning. It is now likely that there will be a fair interval starting about midnight today and lasting till about dawn on Tuesday morning. During this fair interval, and particularly from Monday evening to Tuesday morning, cloud amounts will probably be substantially smaller than given in forecast this morning; winds will also moderate temporarily, particularly over Monday night and at first on Tuesday.

A deterioration will probably set in again during Tuesday; weather on subsequent days will continue unsettled and disturbed.

On General Bull's request this same information was conveyed to General de Guingand (Chief of Staff to Army C-in-C).

2100, Sunday, 4th June. Supreme Commander's meeting.

Since the statement made before the meeting on Saturday evening, there have been some rapid and unexpected developments in the weather situation over the Atlantic. A front from one of the deep depressions in the northwest Atlantic has moved much farther south than was expected and is now traversing the Channel areas. It is almost over Portsmouth now and will clear the eastern Channel at least on the English side overnight. When that front has passed there will be an interval of fair conditions which, from the evidence we now have, should last until at least dawn on Tuesday.

Wind speeds by Monday evening should decrease to Force 3-4 on the French Channel coasts and cloud will become mainly less than 5/10, with base 2-3000 ft.

After that interval, lasting till Tuesday morning, cloud will probably increase to 8/10-10/10 from the west during Tuesday afternoon and will continue so overnight Tuesday.

From a time on Wednesday which cannot be defined from present information, mainly cloudy conditions will continue; but there should be some intervals of broken cloud. In this period from Wednesday to Friday, there will probably be intervals of 10/10ths cloud with base at 1000 feet; these overcast intervals of low cloud may be expected to last 4-6 hours at a time.

Wind will be mainly Force 4 on the English Channel coasts and Force 3-4 on French Channel coasts; in sheltered stretches of the French Channel coast periods of Force 2-3 could be expected. The wind direction throughout will be Westerly.

Additional meteorological statements were made at this meeting in reply to specific questions as follows:

Admiral Creasy (C of S to Naval C-in-C) asked if there was a chance that conditions from Wednesday to Friday might be better than those described in the main statement. He was advised that there was a reasonable chance that the weather systems which were expected to cause the temporary deteriorations after Tuesday would follow a more northeasterly track to Iceland or Southeast Greenland and if that happened the cloud conditions would probably be better than these now forecast. But nothing definite could be said at present about such future developments.

General Eisenhower asked if anything could be said about conditions beyond Friday. He was advised that the forecast even up to then could not be given with any substantial confidence. The general weather conditions must continue to be regarded as disturbed and unsettled; after the very vigorous shake-up in the whole synoptic situation over the North Atlantic which we are going through now, conditions cannot settle down immediately.

But considering the time of year and the evidence we now have, there is a reasonable prospect of weather slowly improving after Friday if the present trend of development over the period Wednesday to Friday comes out as now expected.

A.C.M. Tedder asked about the confidence in the forecast. In reply it was explained that pressure systems had formed, deepened and crossed the Atlantic at a rate appropriate to mid-winter. Confidence in the forecast for more than a short period ahead cannot be high; but there is a fair chance that the low pressure system now in the Newfoundland area will move on a northeasterly track and more slowly than its predecessors; if developments go that way, that should give the azores high pressure system a chance to build up again and at least partially to protect the Channel areas from future depressions traversing the Atlantic from the west.

To A.C.M. Leigh-Mallory and General de Guingand who asked about the detailed cloud conditions expected overnight Monday-Tuesday, the information given was that following the clearance on Monday, cloud over the assault areas and the immediate hinterland would probably remain well broken from midnight Monday to Tuesday morning. The base of this cloud would probably be about 2500-3000 feet and could be expected to be not more than 5/10ths at any time in that area.

Asked by A.C.M. Leigh-Mallory if his meteorological advisors at Hq, AEAF agreed with views presented at this meeting, the reply was that they did; their view was that good though not uninterrupted conditions for visual bombing b heavy and medium bombers could be expected from Monday evening till early forenoon Tuesday; then periods of good bombing alternating with poorer periods after the deterioration on Tuesday-Wednesday had passed.

Naval C-in-C, commenting on conditions for operation of spotting aircraft for naval bombardment, which required cloud base heights not below 2500 feet, was assured that conditions would probably be favorable for these spotting and reconnaissance operations.

(Following this meeting, provisional instructions were issued for launching the assault at 0630 on Tuesday morning.)

<u>0415, Monday, 5th June.</u>

There has been no substantial change in the information available since, or in the forecast presented at, the meeting yesterday (Sunday) evening.

The fair to fine interval which by 0415 had begun at Portsmouth will probably last into the forenoon of Tuesday. During this interval, cloud will be mainly less than 5/10ths, with base at 2500-3000 feet.

Wind on the beaches in the assault area will probably not exceed Force 3 in this interval and will be westerly. Visibility will be good.

During Tuesday, cloud will very probably increase again from the west giving a period of overcast sky with cloud base at about 1000 feet in the assault area later in the day; these cloud conditions will continue overnight Tuesday-Wednesday. Winds will be westerly Force 4 on the English coasts and mainly Force 3 on the French coasts.

Conditions will probably continue unsettled after Tuesday and it is difficult to time further changes. But it is likely that after another front has passed on Wednesday when the 10/10ths cloud at 1000 feet lasting over Tuesday night become broken, the cloud base will increase to 2000-3000 feet though the average amount will probably remain at about 7/10ths. In this period from the passage of Wednesday's front till about Friday, beyond which no useful forecast can be given, there will be intervals of completely overcast sky with cloud base down to 1000 feet. Considerable fair periods of broken cloud can reasonably be expected between the overcast intervals. Visibility will be good throughout.

A.C.M. Tedder said that on Friday and Saturday, the effects of moist warm air coming into the Channel and producing much low stratus cloud had been prominent in the forecast presented. What had happened to clear this air from the Channel so quickly?

There had been considerable doubt about the real synoptic situation on the Atlantic over the last 48 or 60 hours. It had been considered that a front trailing from one depression now off Northwest Scotland was bent away sharply to the west into another low pressure system off Nova Scotia and Newfoundland and that this front did not extend far enough south to come through the Channel areas. This analysis had been faulty mainly because of inaccurate and inadequate reports. The front had actually swept down southeastward and crossed the northern coasts of the Central Channel in the last few hours.

In answer to other questions at this meeting, the following information was given:

(1) There is a reasonable chance after Wednesday of further low pressure systems from the western Atlantic taking a more northeasterly courseinto the Iceland area instead of towards northwest Scotland; if this occurs, the fronts associated with these low pressure systems will not have such an intense effect on the wind and cloud conditions in the Channel and French Coasts.

(2) The situation even after Wednesday must continue to be regarded as disturbed; a quiet settled spell cannot be expected to start immediately after such an intensely disturbed situation. But the time of year suggests that changes after Wednesday may be expected to be in the direction of improvement rather than of renewed or further deterioration to the present intensity.

(Following this meeting, the final and irrevocable decision to launch the assault on Tuesday morning was taken.)

<u>0845, Monday, 5th June.</u>

AC of S, G-3 (Gen. Bull) was informed by telephone (1) that there was nothing further to add to the forecast presented at 0415 and (2) that recent reports had shown that the clearance in cloud cover which had set in at Portsmouth in the early morning hours had not reached the area where the assault would have been taking place until at least 0600. Conditions there were 10/10 low cloud, base at about 1000 feet and had been so throughout the night. Airborne landings and medium bomber support would almost certainly have been impracticable; heavy bombers would have had no opportunity for visual bombing and aircraft spotting for naval bombardment would also have found conditions impracticable. Winds had been and continued a good Force 4 on the beaches.

VII. Brief description of the Weather in Normandy and the Channel

(i) Period 4th to 9th June, 1944:

The two preceding Sections have summarized the meteorological advice given to the Supreme Commander and his staff about the weather likely to be experienced around the scheduled date of assault. This Section provides a summary of the main weather phenomena actually observed during the most critical period, 4th to 9th June, in the Channel and Normandy beachhead.

The summary has been compiled from notes based on reports from operational aircraft and naval vessels and on reports transmitted back by the earliest Meteorological Sections to land with the Expeditionary Forces.

Sunday, 4 June:

0100	Wind:	WSW, Force 2-3.
	Cloud:	2-3/10 high
0400	Wind:	WSW, Force 3.
	Cloud:	No low cloud over beachhead, 9/10, base 1-2000 ft. in Cherbourg Peninsula.
1000	Wind:	WSW, Force 3-4.
	Cloud:	Variable high cloud. Low cloud on Cherbourg Peninsula dissipated to 2-3/10.
After 1000	Wind:	WSW, Force 3-4.
	Cloud:	Small amounts over Channel and Northern France.

Monday, 5 June:

Prior to 0400	Wind:	WSW, Force 5.
	Cloud:	10/10 multi-layer cloud.
0400	Wind:	W, Force 4-5.
	Cloud:	10/10, base 1-2000 ft.
0700	Wind:	W-WNW, Force 4.
	Cloud:	10/10, base 1500 ft.
1300	Wind:	W, Force 3-5.
	Cloud:	7-10/10, base 3-4000 ft.
1800	Wind:	W, Force 4.
	Cloud:	7-10/10, base 4-6000 ft. with broken cloud at 2000 ft.

Tuesday, 6 June:

0100	Wind:	W, Force 3.
	Cloud:	7-10/10, base 3-5000 ft.
0400	Wind:	WNW, Force 3.
	Cloud:	4-6/10, base 3000 ft.
0545	Cloud:	Beachhead clear, with 6/10 low cloud inland.
0800	Wind:	WNW, Force 3-4.
	Cloud:	7-9/10, base 3000 ft., tops near 7000 ft., with 10/10 medium cloud above 11-12000 ft.
Late Forenoon	Cloud:	Clouds broke and cleared over Channel.

1700 Wind: WNW, Force 4, 5 at times.
Cloud: Clear conditions over Channel. Variable amounts of low cloud, mainly 6-9/10 over beachhead and further inland. There was a clear area over the Seine Estuary.

1800 Cloud: At Cherbourg, 4-6/10, base 3-5000 ft.; at Havre, 1-2/10 low cloud, 2-3000 ft., with patchy medium

Wednesday, 7 June:

0100 Wind: WNW, Force 4.
Cloud: At Havre, 9/10, base 2-3000 ft.

0700 Wind: WNW, Force 4.
Cloud: Low cloud became more broken.

During Day Wind: NW, Force 4, decreasing to Force 3.
Cloud: Large amounts mainly 2000 ft. but 1000 ft. locally in showers at first, decreasing and lifting in afternoon. Small amounts at times later, especially near coast.

1800 Wind: At Havre, N-NW, 2-3.
Cloud: 2-3/10.

1800 - 2100 Cloud: Variable, 4-6/10, base 2000 ft. in beachhead and inland.

Thursday, 8 June:

0100 Wind: NW, Force 3-4, Force 4-5 in Channel.
Cloud: Small amounts in Channel, 9/10 broken low cloud Le Havre base 2-3000 ft.

0400-0700 Wind: WNW, Force 3-4, Force 4-5 in Channel
Cloud: Small amounts of cloud over the Channel, 2-3/10 beachhea area, maximum Le Havre, base 3000 ft.

Forenoon Wind: WNW, Force 4, Force 4-5 in Channel.
Cloud: Small amounts of low and high cloud, base 1-2000 ft.

Afternoon and Evening Wind: W, Force 4, increasing to Force 6 by 1800 hours, Force 5 in Channel.
Cloud: Increasing multi-layer cloud, base of low cloud 1000-150 ft rain beginning 1600-1800 hours.

Friday, 9 June:

0100-0400 Wind: W-WSW, Force 5, Force 6 in Channel.
Cloud: 10/10 multi-layer, base 500-1000 ft., light rain.

0400-0700 Wind: WSW, Forcd 3-4, Force 4-5 in Channel.
Cloud: 10/10 multi-layer cloud, base 1-2000 ft., locally 500 f light to moderate continuous rain.

0700-1300 Wind: WSW-WNW, Force 5, Force 6 in Channel.
Cloud: 10/10 multi-layer cloud, base 1,000 ft., light intermittent rain.

Afternoon and Evening Wind: NW, Force 4, Force 5 in Channel.
Cloud: 4-6/10 low cloud, occasionally overcast, base 1-2000 ft. occasional showers.

(ii) Period 17th to 21st June, 1944:

Reference is made in Section VIII (v) to the following paragraphs on weather during this later period:

Saturday, 17 June:

0100	Wind:	NW, Force 4, Force 5 in Channel.
	Cloud:	Overcast, ceilings near 2-3000 ft.
Forenoon	Wind:	N, Force 5, Force 6 in Channel.
	Cloud:	Overcast, ceilings near 2-3000 ft.
Afternoon	Wind:	N, Force 4, but Force 6 and 7 in Straits.
	Cloud:	2-3/10, ceilings near 2500 ft., scattered showers.
Evening	Wind:	N, Force 3-4, Force 6 and 7 in Straits.
	Cloud:	Cleared at beachhead.

Sunday, 18 June:

0100	Wind:	NE, Force 3-4, Force 4-5 in Channel.
	Cloud:	Overcast conditions, ceilings near 2-3000 ft.
Forenoon and Afternoon	Wind:	NE, Force 4, Force 5 in Channel.
	Cloud:	Broken, ceilings near 3000 ft.
Evening	Wind:	N-NE, Force 2-3, Force 3-4 in Channel.
	Cloud:	Multi-layer clouds, causing overcast conditions.

Monday, 19 June:

0100-0400	Wind:	NE, Force 4, Force 5 in Channel.
	Cloud:	Overcast conditions thickened, light rain, ceilings 1-2000 ft.
During Day	Wind:	NE, Force 5 and 6, Force 6 and 7 in Channel.
	Cloud:	Light to moderate rain persisted, ceilings below 500 ft.
2200	Wind:	NE, Force 5, increasing to Force 6 and 7 in Channel.
	Cloud:	Broke to 9/10, rain intermittent, ceilings near 3000 ft.

Tuesday, 20 June:

0100-0400	Wind:	NE, Force 5 and 6, Force 6 and 7 in Channel.
	Cloud:	Multi-layer clouds cleared, and small amounts were observed.
0400-Forenoon	Wind:	NE, Force 5 and 6, Force 6 and 7 in Channel.
	Cloud:	Stratocumulus cloud cover developed, ceilings near 1000
Forenoon and Afternoon	Cloud:	Cloud deck persisted in forenoon but broke to small amounts during afternoon.
After 1800	Wind:	ENE, Force 6, NE, Force 6 and 7 in Channel.
	Cloud:	Low cloud deck re-formed, ceilings near 1000 ft.

Wednesday, 21 June:

0100-
Afternoon Cloud: Overcast conditions, ceilings between 500 and 1000 ft.

Late
Afternoon Wind: NE, Force 5 and 6, NE, Force 6 in Channel.
Cloud: Small amounts of cloud.

VIII. Review of the military decisions as affected by the meteorological advice.

(i) Earlier sections of this report have summarized the procedure adopted for providing meteorological advice, particularly weather forecast advice, to the Supreme Commander and his Staff; a summary of the forecast actually presented has been given (Sections V and VI) and also a synopsis of the weather as it actually turned out to be (Section VII).

Technical details relating to (a) the weather situations and its developments during the critical period, (b) the views expressed by the forecasting centrals, which took part in the meteorological conferences, and (c) some of the problems of forecasting which were encountered during that time - these have been relegated to Appendices A, B and C respectively.

So far as the general Report is concerned, it is desirable at this stage to consider some of the implications of the meteorological advice and the alternatives which might have been adopted. Those matters are reviewed in the following paragraphs.

(ii) General and Preliminary Decisions.

Apart from the fact that the scheduled date for launching the assault was set early in June, and not in May or July, a decision which may well have been influenced much more by military necessity than by information of the type referred to in Section II, the main facts from the meteorological point of view are:-

(1) that the scheduled assault at 0630 on Monday 5th June was deferred on a day-to-day basis from Monday 5th June to Tuesday 6th June, on a weather forecast given 30 hours before the scheduled time of the landings, and
(2) that the decision to proceed with the assault on Tuesday 6th June was taken on a forecast presented on the evening of Sunday 4th June.

It is true that decisions had been taken on May 28th and 31st and June 1st which involved the sailing of naval bombarding forces and the more distant assault Forces, and that those decisions were at least partly influenced by meteorological advice; but it had been made clear that those Forces would not be allowed to sail on the scheduled dates in advance of D Day only if the meteorological advice was that conditions eight days ahead (in the case of the forecast on 28th May and correspondingly shorter periods for May 31st and June 1st) would be prohibitive for the assault in the Channel area and Normandy coast by reason of continued gales or continuous low cloud.

In the circumstances of the weather situation at the time the probabilities were against such contingencies, and the Supreme Commander was advised accordingly (see Section IV).

Decision to defer from 5th to 6th June.

As regards the decision to defer the assault, made provisionally on Saturday 3rd June and confirmed early on Sunday 4th, mainly on a forecast of likely conditions in the central Channel and Normandy areas from 0001 hrs on Monday, the description of the actual conditions given in Section VII(i) shows that cloud conditions were continuously overcast and wind was Force 4-5.

Those conditions continued till at least 0600 on Monday and the improvement thereafter was slow and irregular. It was not till well into the forenoon of Monday that low cloud began to break to any operationally useful extent; wind remained fresh in the beachhead area until the evening of Monday.

It is therefore fairly certain that the weather conditions in Normandy during the crucial hours immediately before and at the scheduled time of launching the assault were prohibitive, at least from the points of view of airborne troop landings, and the actual landings on the beaches; the heavy bombers would have had to operate by non-visual technique and the medium and fighter bombers would have been seriously hampered. Aircraft spotting for naval bombardment would probably not have been practicable.

(iii) Decision to proceed on 6th June.

As regards the decision to proceed with the plan after 24 hours' postponement on the basis of a meteorological forecast presented on Sunday evening, 4th June, Section VII (a), shows that the actual conditions in the hours immediately preceding and following the time of landings, though not the ideal or even the complete minimum requirements, were decidedly better than those on the preceding and succeeding nights.

The surface wind, and therefore the sea roughness, had moderated during Monday evening; and the amount of the cloud and the height of its base at various times of the night and early morning were such as to allow all phases of the assault to be carried out according to plan.

In particular, the conditions for airborne landings were somewhat better than forecast in that the cloud ceiling was at the unusual height of 4000-5000 feet; and by the time the heavy bombers were due to operate, the cloud was sufficiently broken to allow use of visual technique. The medium and fighter bombers were not hampered, nor were the spotting aircraft. The wind conditions on the beaches were within the limits set, though the sea and surf still suffered from the stronger winds of Sunday and Monday.

That the weather deteriorated again during Tuesday and continued poor into Wednesday could not have surprised the Supreme Commander and his Staff; considerable emphasis was put on this deterioration at the meetings leading to the final decision (Section V).

(iv) Possible alternative decisions.

It should be mentioned that the Supreme Commander's meteorological advisors gave much consideration on Sunday, 4th June, to the question of whether conditions for an assault on Tuesday, 6th June would be more or less favorable than on Thursday, 8th June. They understood that as the assault forces from greater distances were already at sea, at least a proportion of them would require to return to base for about 12 hours if decisions went against launching the assault on Tuesday. This would preclude a Wednesday assault.

In this connection, the alternatives from the meteorological point of view were

(a) a reasonable confidence in a favorable interval, even if of limited duration, just preceding and at the time of an assault on Tuesday,

(b) less confidence in an only possibly better interval on Thursday morning.

Keeping in mind the extent to which the whole weather situation had so quickly and intensely been disturbed since Thursday, 1st June, and the proneness of disturbed conditions to continue once they had started (particularly when that start had been so violent for the time of year) it was considered that the alternative (a) should be emphasized

in the advice given to the Supreme Commander. If in fact the conditions turned out so that Thursday, 8th June, would have been a better day for the assault, then those conditions would be equally valuable for the immediate follow-up phase of the operation. Whereas, if the opportunity of favorable conditions overnight Monday-Tuesday were missed, and if information on Monday and Tuesday showed that Thursday would be less favorable than it seemed on Sunday, then the whole position would have become extremely serious from the viewpoint of holding us such a huge and complex operation.

As matters actually turned out, the weather overnight Wednesday-Thursday (7th and 8th June) was probably not quite as good as the weather from midnight on Monday 5th to early Tuesday 6th June, and during Thursday wind increased to Force 6 accompanied by multilayer clouds and rain; by evening, winds were mainly Force 6. These conditions continued throughout Friday with overcast skies of multilayer cloud, base at times down to 500 feet.

The weather throughout the whole period from 3rd June to at least 22nd June (when these notes were written) remained unsettled with intermittent spells of strong wind and cloudy to overcast skies.

(v) Weather a fortnight after the scheduled date for assault

Although the deliberations at the meteorological conferences did not explicitly take into account the contingency of the assault having to be postponed beyond a few days from the scheduled date of 5th June, it is of interest to look briefly at what the sequel might have been had the Supreme Commander found it impracticable to decide on a date in the first batch of possible dates, viz. 5th to 8th June.

In this contingency, it is likely that for other than meteorological reasons the operation would have had to be postponed for a 12-14 day period.

Section VII (ii) shows that the early hours of 17th June would have been favorable for the actual assault and its associated operations, but the immediately following days would have been prohibitive for the follow-up and early build-up phases. Force 5 winds with Force 6 and even 7 at times from a northeasterly direction with long periods of overcast sky and low ceiling (1000 feet or less) would have seriously hampered all naval and most air operations, as indeed they did, though at a somewhat less critical stage of the operation.

IX. Comments and Recommendations

1. General

The following paragraphs summarize some of the more important impressions and views derived from taking part in the meteorological arrangements and in the presentation of forecasts and information. The comments are not offered in any sense of criticism; they are included in this report primarily in the hope that they may be of use in any similar circumstances that may arise in the future.

From the viewpoints both of the procedure adopted for obtaining the meteorological advice, and of the complexity of the operation for which the advice was given, the arrangements were probably unique; it is therefore not surprising that the arrangements were not perfect. But the experience gained should be of value for the future and it is the aim of this Section to indicate along which lines improvement might be sought.

2. From the Military Point of View

(a) Information on Operational planning made available to Meteorological advisors.

The Meteorological Section was not set up at Supreme Headquarters until a considerable time after the initial plans for the operation had

been made, but facilities were provided for the Section to become conversant with whatever details were necessary for giving meteorological guidance in the later planning stages. Besides access to relevant papers opportunity was given for discussion with the planning authorities.

This latter aspect is important in all military operations. With a technical and complex subject like meteorology, written statements (or "appreciations") about likely implications of meteorological factors on an operation are a very poor substitute for oral discussion with the appropriate authorities.

From the viewpoint of the operational staff such discussion allows the meteorologist to explain the implications and significance of aspects of meteorological information which are liable to be overlooked and at the same time care can be taken to ensure that unwarranted emphasis is not attached by the operational staff to weather statistics.

From the opposite angle, the meteorologist learns by discussion much better than by paper statements which aspects of weather at which precise times are most important from the operational standpoint and so can give more effective advice whether it be in planning or in decisions on actual operations.

A case in point was the airborne part of the NEPTUNE operation. According to the requirements as set out in Section I(b) a cloud ceiling of 2500 feet had been accepted as the minimum along the route from base to target and over the target area. But on the 3rd June when it became fairly certain that cloud conditions were likely to be poor on the night of the 4th-5th, discussion with the ultimate authorities elicited the information that airborne landings might be effectively made with a 10/10 cloud ceiling at or even somewhat below 1000 feet.

(b) Elasticity in selection of D-Day

With the magnitude, range and complexity of the military and political factors concerned in the NEPTUNE operation, elasticity in decision must necessarily be limited. Even such details as tides, light and clearance of under-water obstacles practically pre-determine when such amphibious operations must be launched. Nevertheless NEPTUNE was deferred one day and would doubtless have been further deferred had weather prospects justified it.

The inference is that no matter how complex the operation is, plans should always allow for a postponement because of weather. In the last resort the success of the initial landings and therefore of the whole operation is determined by weather conditions allowing effective co-operation of all arms.

(c) Rehearsal of procedure involving meteorological advice leading to Military decisions.

As had been described in Section III, the Supreme Commander's Staff arranged for meteorological briefings for dummy D-days to be given in the weeks preceeding the actual operation. It was realized that the actual making of the final decision, taking into account the likely weather conditions, was an important phase of the whole operation.

This was an effective and profitable innovation in military operations and one that should be followed in similar operations in the future. It might have been even more profitable if the weather in South England and the Channel in the weeks before the invasion had not been so consistently good. For the complete break in the weather at the time when the real decision had to be made introduced complications which could hardly have been provided against with the blue skies and light breezes which formed the background of most of the rehearsals.

3. From the Meteorological Point of View

(a) The procedure for obtaining the agreed Meteorological Advice

There are inherent defects in the kind of meteorological procedure

adopted for the NEPTUNE operation. So long as accurate weather forecasting involves a subjective analysis and interpretation of observational data with a blended background of experience and technical knowledge which necessarily varies with each individual forecaster, so long will forecasting centrals with the same basic data produce different forecasts of future weather.

Such differences in interpretation and analysis cannot adequately be resolved by telephone conferences, howerver frequent. Aids such as facsimile reproduction processes for synoptic charts might reduce some of the differences by ensuring that each of the advising Centrals realizes clearly what different premises the other centrals are using for making their forecasts. But in the circumstances described in Appendix A where it is shown that interpretation of a report from one ship was all-important, it is doubted whether an interchange of each other's synoptic charts by facsimile process would have helped. As in the meteorological conferences at that time, each Central would naturally adopt the interpretation which best fitted its general trend of analysis.

Another aspect of this same matter is the drawback arising from the need for achieving and disseminating an agreed forecast for coordinating the meteorological advice at operational levels. As soon as a main decision is made for starting complex operations of the NEPTUNE nature, instructions are issued to the various force commanders, Naval, Air and Ground, both U.S. and British, to proceed with the execution of the plan. It is therefore necessary that the meteorological advice given to these force commanders does not conflict with the advice on which the primary decision has been taken. This necessitates that each of those advisors be provided with a statement of the forecast on which the advice to the Supreme Commander has been based, and this in turn requires that the outcome of meteorological conferences on which the Supreme Commander's advisor has based his views be framed in strict meteorological terms.

Now it is one thing to convey orally a description of future weather, stressing aspects that are essential and minimizing others sufficiently to allow decisions to be made; it is another thing to commit such advice to paper in a way which will be useful to meteorological advisors at specialized operational formations. To be of any value to such advisors, the statement requires definition of the timing of weather sequences, the intensity of the accompanying weather, the specific localities affected and so on. And to get a number of forecasting Centrals to agree to such a detailed statement on occasions when, for example, passage of fronts cannot be accurately timed, either means that only one of the Centrals' advice must be taken, or that the statement must be so worded for acceptance by all the Centrals as to be of little value to the meteorological advisors at operational formations.

It is not clear what the solution to this difficulty may be for future operations of this kind. One solution might be to establish one Central at which the best qualified and experienced representatives of the various meteorological services concerned work together instead of in separate institutions connected only by wires; it would be agreed beforehand by the various services concerned that the forecasts issued by that Central would be accepted by all the services involved in the operation. This kind of arrangement is known to function on the military side, but whether meteorological services could be fitted into a similar framework is questionable.

A second solution might be found on the lines of restricting the function of the conferences solely to providing an exchange of views about analysis and future trends and developments; there would be no responsibility at the actual time of the conference on the part of the chairman to find an agreed development and forecast acceptable to all the participating Centrals.

With the views of the Centrals in mind, the Chairman would use his own discretion as to which, if any, of the sets of views offered he would adopt as the basis of the advice to be given to the Supreme Commander and also to be used in framing coordinated forecasts for distribution to the meteorological sections at operational formations.

(b) The value of long range forecasting in military operations.

Reference has been made elsewhere in this report to the accuracy of forecasts for more than 24 or 36 hours except in stable weather situations. Cursory examination of the series of 5-day forecasts submitted to the Supreme Commander and his Staff during April and May, 1944 has shown that even in the rather abnormally stable weather circumstances of those months, the operational value of forecasts fell away quickly after the second or third days after the issue of each forecast; when the synoptic situation was changing rapidly, the forecasts frequently required substantial modification before the first day was past. If specific details of cloud, wind and visibilities for limited areas had had to be included in each forecast, even this 24 hour period might well have been too long in some types of English weather.

Although every effort should therefore continue to be made by the various Meteorological Services in improving their several techniques for extending weather forecasts beyond 24 hours, it has to be appreciated that at the present time forecasts in sufficient detail to be of operational (as distinct from planning) value can seldom be made with useful confidence for more than a 24 hour period in advance.

For assistance in planning, statements can be made to the effect that "weather is likely to continue to be unsettled with considerable general cloudiness though with intervals of well-broken cloud and good visibility", or, in more exceptional circumstances, that "mainly settled weather will persist for next few days with light, moderate northwesterly wind and well broken cloud, minimum at night". But the discovery of a technique by which even first approximations to such details of weather as are required for specialized operations can be forecast as a regular daily procedure with useful accuracy for any day more than two or even more than one day ahead still remains a matter for future research.

APPENDIX A

Description of the Synoptic Meteorological Situations and Their Developments over the Period 1st to 6th June 1944

1. Introductory Remarks.

The material in this Appendix and Appendices B and C is primarily of technical (meteorological) interest. The aim in compiling these Appendices has been to reconstruct some of the problems with which the Forecasting Centrals were confronted during the critical phases prior to launching operation NEPTUNE.

The paragraphs which follow contain a suggested post facto analysis of the weather situation covering the period of operational interest. Though every care has been taken to utilize every piece of evidence in reconstructing the situations, the analysis is not necessarily a final statement capable of acceptance by all the meteorological authorities; it is primarily intended for consideration in conjunction with the forecasts offered to the Supreme Commander and his Staff (Sections V and VI) and secondarily for appreciating the difficulties with which the forecasting Centrals contended during the conferences summarized in Appendix B.

Particular mention should be made at this stage of the vital assistance in the analysis and forecasting provided by ships which had been assigned to predetermined locations in the Atlantic by the United States Navy and the British Admiralty. The United States Navy augmented their regular complement of six ships by two additional ships for the critical period. These eight ships operated mainly west of 30°W. The British Admiralty provided two ships from Day D-7, one to function between 20 and 25°W longitude, due south of Iceland and the other in a similar longitude north of the Azores.

2. General Comment.

Some of the main difficulties of analysis are referred to as they arise in subsequent paragraphs; they were such that at the time it was possible for the forecasting Centrals to differ from each other by as much as 10 mbs. in their interpretation of the pressure in an important area, and even after the event it is difficult to place much confidence in any reconstructed chart.

The critical developments took place in the area bounded approximately by 55°N-60°N and 15°W-35°Wm between the early hours of the 2nd and midnight of the 4th. The western section of this area (25°-35°W) is normally an "empty" area from the viewpoint of reports; normally, the eastern section is at least partially covered by the "Bismuth" meteorological reconnaissance flight, and during the time of the operation a ship reported from the area between 22° and and 25°W, and 52° and 59°N.

When movement and development is rapid, the interpretation of reconnaissance flights is a matter of considerable difficulty; past experiences have led the majority of forecasters to treat aircraft pressure reports with great caution. In the event the reports from the single ship became all important, and it is greatly to be regretted that at the critical time (from both the synoptic and operational viewpoints) very substantial doubt was introduced into the definition of the situation by a jump of 20 mbs. in reported pressure; this was repeated in the next observation then, and the discontinuity followed. In addition, the ship began its southward run on the 2nd, and was to the south of the area of maximum development on the 3rd and 4th. When this is considered in conjunction with the somewhat unreliable reports to the south of Greenland on the 1st, there can be no surprise at the existence of considerable differences in analysis between the Centrals.

It should also be remembered (a) that the period under consideration followed a long spell of mainly anticyclonic conditions and (b) that during the period when the main decision had to be taken a situation developed which can only be described as very disturbed even by winter standards.

The charts (reproduced as Figures 1 to 7) which have been prepared for use with the following notes represent the reconstruction by the Meteorological Section, SHAEF, of the main essentials of the synoptic pressure distributions during the period 1st to 6th June. The series of charts used by each Central at the time probably differed in greater or less detail from Figures 1 to 7.

2. (continued)

Upper Air Contours.

Figures 8 to 11 are included for the purpose of indicating the general nature of the upper air circulation on 5th and 6th June. In those figures the bold continuous lines are pressure contours drawn for each 200 feet: the thinner dotted lines are isotherms (5°C) and the very thin continuous lines confined to the British Isles and immediately adjacent areas are "thickness lines" in 200 feet intervals between the 750 and 300 mb. levels. Short heavy arrows represent flow of cold air between the levels of 750 and 300 mb. and the short skeleton arrows do the same for warm air. Arrows connecting encircled courses indicate trajectory of the associated systems, and black arrows with W or K show advection of warm or cold air at the 500 mb. level.

The figures 8 to 11 have been supplied by the Director United States Weather Services to whom acknowledgement is made for permission to reproduce them.

3. Analysis

At 0100Z on 1st June, a complex low presure trough extended from a shallow centre to the west of Scotland (L1)* southeastward over the British Isles. A cold front lying north to south over central France was moving east. Pressure was high in the Jan Mayen region with a flat ridge down to the North Sea. A ridge from an anticyclone centered over the Azores extended into the south of the Bay of Discay.

A comples depress ion east of Newfoundland (L2) was moving northeast, and a further depression (L3) was forming in the St. Lawrence region.

A wave disturbance (L4) with no closed centre but with very warm moist air in its warm sector to the northeast of Bermuda was moving northeast (Fig. 1).

The 500 mb chart showed a centre to the south of Greenland, with a col between Iceland and Scotland. The air between Greenland and Iceland was warmer than that immediately to the south, with cold air over Scandinavia. There was a strong west southwesterly flow from southeast of Newfoundland to the col, and strong easterlies over south Greenland.

During the 1st, L1 moved east towards northern Scotland, and cold air from northern Scandinavia moved westward on the southern side of the Jan Mayen high, with the formation of a col at the surface and at 500 mb to the south of Iceland.

2nd June

It seems probable that a trough from L2 developed to the east with the main centre following more slowly (at 20-25 mph) on an east northeasterly track; but the detail in this area is obscure owing to the corrupt and conflicting nature of the few reports available in the area south of Greenland. The depression has a complex history and seems to have had two separate centres at 0100 on 1 June. However, a front (probably the occlusion of L2) passed the ship in 57°N 24°W between 0100 and 0700 on the 2nd. There is also little direct evidence of the progress of the tropical air in the wave L4; but at 0900 hrs. it had reached the ship at 51°N 32°W. In this vicinity it would come under the influence of the cold front of L2, and by 1300 on the 2nd it is probable that a complex wave was forming in the region 50°N, 30-35°W. In the meantime, L3 had moved into a position east of Newfoundland. (Fig. 2).

The 500 mb chart on the 2nd showed a very strong west southwesterly sweep from south of Newfoundland to Scotland, with the warmer air between Greenland and Iceland being displaced by colder air from the east and an elongated col from south of Iceland to south Norway. Conditions has then become suitable for cyclonic development in the region between Iceland and Scotland.

Developments in the 24 hours after 1300 hrs. on the 2nd are difficult to follow, particularly in view of the nature of the reports received from the ship in about 55-57°N 25°W. There is some evidence that the pressures reported by this ship were for a time low by an amount of the order of 5 mbs. but this is not certain. The confusion was increased by a jump of 20 mb in reported pressure from the same ship at 0300 on the 3rd; this discontinuity was maintained by the 0600 report but had disappeared by the time the 1000 report was received.

At 1300 on 2nd June, the diffuse warm front of L2 had spread into west Ireland, and pressure was falling in the region 25°W, where the wave L4 was approaching the trough of L2, resulting in a low pressure area of complex frontal structure.

3rd June

The cold front of this depression appears to have passed the ship at 55°N 22°W between 0100 and 0300 on the 3rd, but there was no appreciable rise in pressure, and the front does not appear to have passed far south of this point before returning as the warm front of L3. The ship was again in warm air by 1600 hrs on the 3rd.

* See Figs. 1 to 7 for positions of pressure systems identified by symbols in these paragraphs.

In the meantime, cold air had been spreading south to the east of an anticyclone in the Hudson Bay area and the eastward movement of colder air to the south of Greenland had continued. The result was the establishment of an intense west-southwesterly gradient at 500 mb. from Newfoundland to Scotland with a flat area from Labrador to the Faroes. In this intense gradient the systme L3 appears to have moved quickly east, the cold front progressing at about 40 mph, passing a ship in 51°N 33°W between 1300 and 1600 on 3rd June. During this rapid movement, the centre would not be expected to deepen appreciably and a trough would probably be left in about 55°N to 60°N. The very moist warm air of L4 had spread into the west of Ireland by 1300 on the 3rd, and the considerable pressure falls in this region which had first appeared on the 0100 chart continued after the passage of this warm front.

During the 3rd the depression L6 formed in the region of Nova Scotia; and, drawing polar air from the Hudson Bay anticyclone, began to deepen very rapidly whilst moving ENE. The suggested position of low pressure systems and major fronts at 1300 on the 3rd are shown on Fig. 3.

4th June

The rapid easterly motion of L3 and the deepening of the complex system L5 continued, and the cold front of L3 passed the ship at 52°N 20°W between midnight and 0400 on the 4th, and was over Ireland by 1300 hrs. By this time the circulation of L3 had combined with L5 and the centre was moving more slowly. There had been considerable deepening late on the 3rd, which continued on the 4th. A suggested analysis for 0100 hrs. 4th June, is shown of Fig. 7, with tracks of the low pressure systems.

During the 4th June, the cold front of the combined depression L5 continued to move across the British Isles, with an average speed of about 30 mph, whilst L6 deepened very rapidly indeed, with the centre slowing and moving NE or N. This simultaneous deepening of L3 and L6 was a most remarkable development. The strong westerly flow at upper levels was distorted by the two deepening and occluding depressions and an intense NW'ly gradient developed at upper levels to the west of the British Isles. A very sharp and deep upper air trough moved over the country, the trough line being about 400 miles behind the surface cold front of L5 on the 5th, and rises of pressure at the surface were inappreciable until the upper trough line had passed.

5th June

The frontal systme of L6 was carried forward to the south of the centre, which continued to move slowly NE on the 5th. The surface warm front was carried forward almost to the ridge line, over which there was a fairly strong gradient at all levels. In these circumstances no building of the ridge could be expected, and pressure in the col between L5 and L6 probably remained at about the same level (1010 mbs.) throughout. L5 probably attained its maximum depth about 0100 hrs. on the 5th when it was estimated at below 975 mbs. in 60°N 5°W. It was moving very slowly East, and by 0700 hrs. was filling rather rapidly.

By 1800 hrs. on the 5th, L6 had reached its maximum depth, a pressure of 975 mbs being reported near the centre at 55°N 45°W. The col was then in the neighborhood of 60°N 22°W and the centre of L5 just north of the Shetlands. By this time warmer air had been carried well round the north of L5, isolating a pool of colder air in the eastern North Sea. Rises in this region were small, and the tendency for a

southeastward transference of the centre of lowest pressure was obvious by 0700 hrs. on the 6th; a gradient of 25-30 mph. from the northwest was maintained over the Channel area throughout the 6th by this means. The surface warm front of L6 had been carried forward to the ridge line, and its outward movement had ceased by 1300 hrs on the 6th. Thor upper winds over Western England and the Channel during the 6th reached a speed rare even in disturbed winter conditions.

APPENDIX B

Summary of views of the Forecasting Centrals as expressed at the Meteorological Conference held from 1st to 6th June.

1. Introductory Remarks.

(a) Sections 2 to 4 of this Appendix summarise in the form of brief notes the views of the three forecasting centrals on synoptic developments covering the period of decisions for launching the assault; they are based on notes made hastily during the meteorological conferences by telephone. The Figures 1 to 7 referred to in the notes and the nomenclature adopted for the various pressure systems are as described in Appendix A, particularly Section 2.

(b) Although the series of synoptic charts reproduced as Figures 1 to 7 are referred to in the brief summary of analysis in Section 2 as if they constituted the single and unique series of charts which each central used at the time of conferences, the charts are post facto reconstructions prepared by the Meteorological Section SHAEF: each of the Figures 1 to 7 is known to differ in greater or less detail from the actual working charts used by the centrals at the time of the conferences.

These differences naturally have important bearings on the significance of the views expressed by the Centrals as briefly summarised in Section A below. To do complete justice to each Central it would have been necessary to reproduce three sets of charts, one fore each central. But early enquiry with this in view made it clear that it would not be practicable to obtain reproduction of the charts exactly as they were when the discussions took place.

It was therefore considered that the best course was to draw one independent set of charts using all the later data and subsequent history of developments: it was realised that this set of charts in all probability would not be accepted by any of the centrals and would make the analysis as summarised below appear too pessimestic or too optimistic. But it would serve the purpose of illustrating the general trend of development as envisaged by the centrals.

(c) Another aspect of the conferences should probably be kept in mind in reading the summary of analyses. The conferences were hardly ever shorter than one hour and sometimes extended to almost two hours: it cannot therefore be expected that the views expressed by the centrals can be adequately compressed into a very btief summary. Further, that central which opened the conference - the opener changing in rotation - generally presented a comprehensive analysis, and the presentations of succeeding centrals were mainly confined to emphasising points of difference. It therefore comes about that the summaries of the analyses tend to lay undue stress on differences of opinion and make little or no mention of those important aspects of the analyses which were more or less agreed by all the centrals.

(d) Little mention has been made in these notes of the actual forecasts of weather in the Channel made by each central; it is, however, probably a fair summary to say that Dunstable expected a westerly flow into the Channel area of the moist humid type of air, with a high average cloudiness and low base height. These conditions were forecast to return after a brief interval when it became clear that the cold front would pass through the area. For the whole of the period, Widewing, on the other hand, tended to minimise cloud amounts and wind strength in the Channel, basing their argument on the maintenance of relatively high pressure from the Azores to North France, with the moist humid air being carried further North. When it became clear that the cold front (of L3) would cross the area, the view was unchanged as a wedge development was expected behind it. The Admiralty central generally maintained a view midway between the two.

2. Brief Summary of Central's Analyses.

Evening, 1st June.

Dunstable:- L1 is expected to move east and deepen; L2 coming out at 60°N to into frontogenetic region lying east to west in 60°N to north of Scotland. Generally cloudy westerlies in Channel area. Lows not intense. Agreed that there would be a tendency to fill as lows moved south of Iceland, and regenerate in Norway region.

Widewing:- Strong upper easterly airflow over south Greenland is preventing rapid eastward movement of lows. Azores ridge building up to north and northeast. L1 moving east and deepening. Anticyclonic conditions will develop later in Channel areas.

Admiralty:- L1 expected to move east-southeast and deepen. Ridge building temporarily behind it. L2 probably held in west Atlantic, but perhaps moving east, filling slowly, followed by L3, bringing cold front through Channel on 6th June.

Morning, 2nd June.

Dunstable:- Situation deteriorating with strong westerly flow developing aloft, L2 less deep but coming through, followed by L3. (Cold air from Scandinavia area spreading west and replacing warm air to the southeast of Greenlnad.) The result expected would be a fairly vigorous westerly type of weather but with cold fronts not reaching Channel area. Warm air with much low stratus in Channel.

Widewing:- Azores pressure rising and L2 filling. Cannot agree that westward spread of cold air from Scandinavia will favour eastward passage and deepening of L2. Warmest moist humid air on Atlantic spreading east into northwestern districts of the British Isles, but not affecting the Channel area, which is expected to have little cloud.

Admiralty:- No change of view. Sluggish movement of shallow depressions from west for some time: slightly more pessimistic than yesterday.

Evening, 2nd June.

Dunstable:- Situation more obscure. Depressions on Atlantic not intense, but danger of intensification in region between Scotland and Iceland. Small system with tropicalair to northwest of Azores (L4) moving northeast. Channel area in flow of moist warm air round the Azores high with falls of pressure to the northwest causing winds to back sufficiently to push low stratus cloud up Channel.

Widewing:- L3 not expected to move east rapidly. Azores ridge expected to be oriented in a more northeast-southwest manner than hitherto, with axis extending into the Channel area until 5th; at later stage the wedge axis will retreat south. No fronts coming through Channel during the critical period.

Admiralty:- Still expect L2 to move east as a feeble system in about 60°N with following systems taking a more northerly track as Arctic anticyclone is transferred slowly westward to Greenland. Not hopeful about cloud conditions for 5th, as light westerlies are expected in Channel.

Morning, 3rd June.

Dunstable:- Some clarification. Frontal zone from Nova Scotia to northwest Scotland with wave in mid-Atlantic coming across (L4), followed by L3. Polar air behind L3. Warm moist air still expected in the Channel area during the period.

Widewing:- Holding to previous ideas of development. Although pressures are falling in Ireland, pressure still rising at upper levels to the West, (Epicure ascent.) Upper rises from the west; on extrapolation, these rises come into British Isles in 24 hours' time. Falls of pressure occuring in Ireland are due to approach of warm front of L2. No cold air to intensify the system so ridge expected to build behind this front. Conditions expected to be 5/10 cloud or less through Wednesday in Channel areas.

Admiralty:- No change of view.

Afternoon, 3rd June.

Dunstable:- Great reservoir of polar air in the north from Russia to Canada but no indication of break through except behind L6: L6 will move eastward and should be near Scotland on Wednesday morning. After warm front of L5 has gone through Channel area tomorrow, Channel will be in WSW air flow of moist humid air, until Wednesday.

Widewing:- L5 moving east. L6 moving northeast, then slowing and moving into Denmark Strait absorbing L3. Fronts of L6 coming through, perhaps with minor development at point of occlusion. Cold front of L5 coming through but inactive south of 52°N. Main cold front of L6 possibly retarded by further wave development. Flat ridge crossing British Isles ahead of fronts of L6; ridge line will be over North Sea on the 6th.

Admiralty:- Situation still borderline. L5 slowing down moving NE (pressure falling in southern Ireland). L3 not important; but ENE movement of L6 will be rapid with outbreak of cold air behind it. Possible that cold front may come through our areas before cold front of L6.

Evening, 3rd June.

Dunstable:- Similar to morning analysis. Situation becoming unpleasant. Complex low to south of Iceland (L5) moving east. Cold front extimated just south of 54°N at 0700 hrs. and not expected through Channel area as L3 would follow L5 eastward across the Atlantic, followed in turn by L6. Cold front coming through behind L6 probably on 7th or 8th. Tropical air in Channel area during the period 5th to 7th.

Widewing: - Immediate development will be L5 moving east-southeast into North Sea, with active cold front through the Channel on 4th-5th. L3 and L6 moving to south of Iceland with cold front of L6 reaching British Isles on the 8th.

Admiralty:- Small low near northwest Scotland (L5), with associated wave running ESE across Scotland, expected to move east-southeast; low L3 slowing down and moving northeast. Atlantic ship reports not showing substantial falls. L6 will have cold outbreak behind it and probably move into and absorb L3, the combined centre eventually moving into the Norwegian Sea. Tropical air from L4 still well to west but reaching Channel area on the 4th. Possibility indicated that cold front of L5 will come through, but this was discarded later in the evening. Azores ridge expected to move southward and weaken with first cold frontal passage (front of L3) on 7th and another (cold front of L6) on 8th.

Morning, 4th June.

Dunstable:- Little change in picture. Cold front of L6 will move to West of Ireland on 6th, trailing into the Channel area on Wednesday, 7th. Centre of L6 might be held back in western Atlantic.

Widewing:- Expects axis of finger of high pressure Azores- North France not to move much, but some decrease of its intensity is indicated. Broad southwesterly flow on Atlantic with zone of activity far enough to northwest (Cape Hatteras to 60°N 10°W) to allow of good conditions in Channel.

Admiralty:- L1 and L3 have combined and will continue to deepen. Ridge from Azores to Biscay weakening in east and will allow fronts to come through. L6 moving rapidly east at the moment and cold front may be through Channel early 7th. Deterioration in situation supports more pessimestic parts of previous analysis.

Afternoon, 4th June.

Dunstable:- Cold front of L5 well to south, position not known, but not south of 48°N in 30°W. Doubtful of development of wedge between L5 and L6 as reports in this region are conflicting. Still consider L6 will continue to move east with L5 moving northeast fairly slowly. Cold front of L5 passing through Channel areas on 5th but trailing across France. Strong front (warm front of L6) well forward into Atlantic wedge so ridge effects should be minimised.

Widewing:- L5 moving northeast. L6 moved into Denmark Strait area, with fronts approaching Ireland on Wednesday. Mainly flat wedge conditions over Channel area with temporary deterioration at front of 8th.

Admiralty:- L6 moving into Denmark Strait. L5 moving northeast. Atlantic wedge building slightly and coming in, but remaining flat. Occlusion of L6 in west Channel on 7th, with good wedge behind.

Evening, 4th June.

Dunstable:- L5 not expected to have passed Shetland on the 5th, therefore still expect L6 to move east, not northeast. Ridge between L5 and L6 weakening. L5 moving northeast to Norway coast on 6th, and filling. L6 south of Iceland Tuesday morning, with wave on cold front. Disturbed conditions after 6th.

Widewing:- L6 expected to Move NE so that by midday 5th June its centre will be about 59°N 35°W with 980 mbs. centre, and by midday 6th June at 64°N 35°W with 990 mbs. centre.

Admiralty:- Cold front of L5 through area early 5th, linking back through flat wedge to warm front of L6. L6 expected to move into Iceland area and fill. Warm front of L6 near Scillies by 1300 hrs. 6th, moving east slowly. Cold front of L6 through Channel area on 8th or 9th.

Morning, 5th June.

Dunstable:- Now agree that L6 not moving east as anticipated, but wedge in advance of centre has front across it and will not build any more. Warm front of L6 expected to move into west Ireland by evening of 6th.

Widewing:- Situation as anticipated. L6 not moving East. Wedge between L6 and L5 is building; fronts as anticipated on the 4th.

Admiralty:- L5 moving very slowly. L6 moving north but fronts coming throug British Isles. Warm front reaching west Ireland by evening of 6th. Wedge between L5 and L6 not pronounced but building a little.

Afternoon, 5th June.

Dunstable:- No material change of view. Warm front in the assault area about mid-day on 6th. Extensive cloud under inversion in wedge which is not expected to build up. (Front has moved forward almost to wedge line.)

Widewing:- L6 stationary. L7 moving into it and eventually into Davis Strai L5 and low pressure at point of occlusion of L6 moving slowly east-northeast, then northeast. Large anticyclone to east and west of Azores with flat ridge over west Atlantic and British Isles. Effect of frontal passages British Isles minimised.

Admiralty:- Little change in view from morning. Warm front of L6 expected in assault area about mid-day 7th. Cloud breaking in wedge during night of 5th-6th.

Evening, 5th June.

Dunstable:- L5 filling, moving very slowly northeast. L6 moving slowly northeast with L7 moving into it. No change of cloud forecast.

Widewing:- No change.

Admiralty:- L5 filling and moving slowly northeast. Azores high moving east-northeast with ridge building again over France. No change in timing warm front of L6. Winds less than Force 4 in Channel.

Morning, 6th June.

Dunstable:- Little change. L5 now stationary and warm front of L6 retarded somewhat.

Widewing:- Still substantially same analysis. Expect warm front of L6 will dissipate south of 51°N. Cold front expected 8th or 9th.

Admiralty:- No substantial change but warm front retarded somewhat.

APPENDIX C

Notes on the Problems of Forecasting, 1st to 6th June

1. General

It has been explained in the preceding Appendices that the principal forecasting problems arose from the difficulty of analysis of each current forecasting chart in the series. Even in retrospect this is not surprising. Apart from the obscurity of the actual pressure distributions over the most important areas of the Atlantic, the general level of activity rose rapidly over the most critical period to a level far above the normal, even for disturbed conditions in summer.

The pressure reading of 976.8 mb. at Wick at 0400 on 5th June was probably the lowest June reading on record in the British Isles. The previous lowest, 978.3 mb. at Malin Head on 11th June 1926 was recorded in the Meteorological Magazine (Vol. 61, p.155) as the lowest for at least half a century. This makes the 5th June 1944 reading the lowest for at least 68 years and probably the lowest on record.

Apart from this isolated pressure, a search through the synoptic charts of the last forty years has shown that during this period there has been no situation of similar intensity (two depressions with centres below 980 mbs. simultaneously in the Atlantic) and rate of development within the period 15th May to 15th June.

A reluctance to forecast movements of systems across the Atlantic at an average speed of 40 mph. or more in June therefore hardly requires justification.

2. The operational forecasts and the Weather in the Channel area from evening 4th June to evening 6th June

The assault was originally planned for the morning of the 5th, and the decision to proceed had to be taken on the evening of the 3rd, with a possibilit of last-minute cancellation early on the 4th. Until early on the 3rd, it had seemed that a light or moderate West to WNW wind was reasonably assured, the difficulty being to predict amounts of low cloud.

The proximity of the ridge line made it rather doubtful whether the subtropical air in L4 (see Fig 1 - 6) would reach the Channel area with its consequen of very low cloud. The fact that falling pressure in West Ireland continued after the arrival of the main warm front indicated that conditions were liable to be much more disturbed, but a firm forecast as opposed to a statement of possibilities could not be made.

The arrival of the cold front on the 4th set these doubts at rest, and on its passage through the Channel area on the night of the 4th-5th it gave rise to Force 5 winds, with rain and much cloud at 1000 feet or below. Those cloud conditions were not clear of the assault area until after 0600 on the 5th.

Hence, although the cold front did not figure in the forecasts issued on the 3rd, the cautious attitude necessitated by the continued pressure falls were fully justified in the event.

The difficulty of producing a detailed 36 hour forecast in disturbed conditions is well brought out by the fact that the cold front was far beyond the range of the routine meteorological reconnaissance flights (to about 25°W) made on the 3rd, and would have been beyond the range of a special flight timed to report at the last possible moment if such a report had been made available.

During the 4th, the situation clarified somewhat. It became evident that the rapid eastward movement of centres had been broken by the deepening of L6 and the main problems became the determination of the speed of eastward movement of the fronts of L6 and the nature of the wedge between L5 and L6. Advice was needed on the evening of the 4th, with a view to assault early on the 6th, and the

synoptic picture on which this advice was based was a flat wedge moving east, with the warm front of L6 approaching the West Channel on the morning of the 6th. This would mean light to moderate westerly winds, with little cloud for the immediate assault, followed by a great deterioration to generally cloud conditions after midday on the 6th. In the event the centre L5 began a southeasterly movement on the 5th, whilst continuing to fill. A northwesterly gradient was maintained over the Channel areas, but did not reach its maximum until after the actual assault. There can be little doubt that there were Force 5 winds for a time on the beaches on the afternoon of the 6th, but not during the actual assault. This development held back the surface warm front, and the very damp air did not penetrate the Channel. Nevertheless, the warm air aloft played a part in conjunction with a series of upper level troughs in the maintenance of a thin but persistent layer of cloud at low medium levels, which greatly reduced the diurnal variation of the lower convective cloud. This diurnal variation was, however, sufficient to produce large local clearances by dawn on the 6th, and again on the afternoon of that day.

The southeastward movement of the centre was not forecast on the 4th, though it had been suggested by Widewing on the evening of the 3rd when the situation was less clear. The movement of the centres of rapidly filling occluded depressions, particularly when the history was as complicated as that of L5, is not a matter on which any firm opinion can be expressed. It is perhaps surprising that this movement was not mentioned as a possibility, but it could only have been put forward as the worst possible movement from the point of view of Channel weather. On the morning of the 4th it was a much more obvious possibility. This is yet another illustration of the difficulty of forecasting details over a period of about 40 hours in disturbed conditions.

3. Long Range Forecasting Techniques

Reference is made elsewhere (see e.g. Section IX), to the assistance given by the various long range forecasting methods used by the Centrals; here it can only be remarked that it is doubtful whether the views of any of the Centrals were greatly influenced during the critical period by the semi-statistical methods mainly employed. They may perhaps have been useful as confirmation of views arrived at by more normal sysnoptic methods and may therefore have had an appreciable effect on the confidence with which those views were put forward.

4. Observational reports

See paragraph 2 of Appendix A.

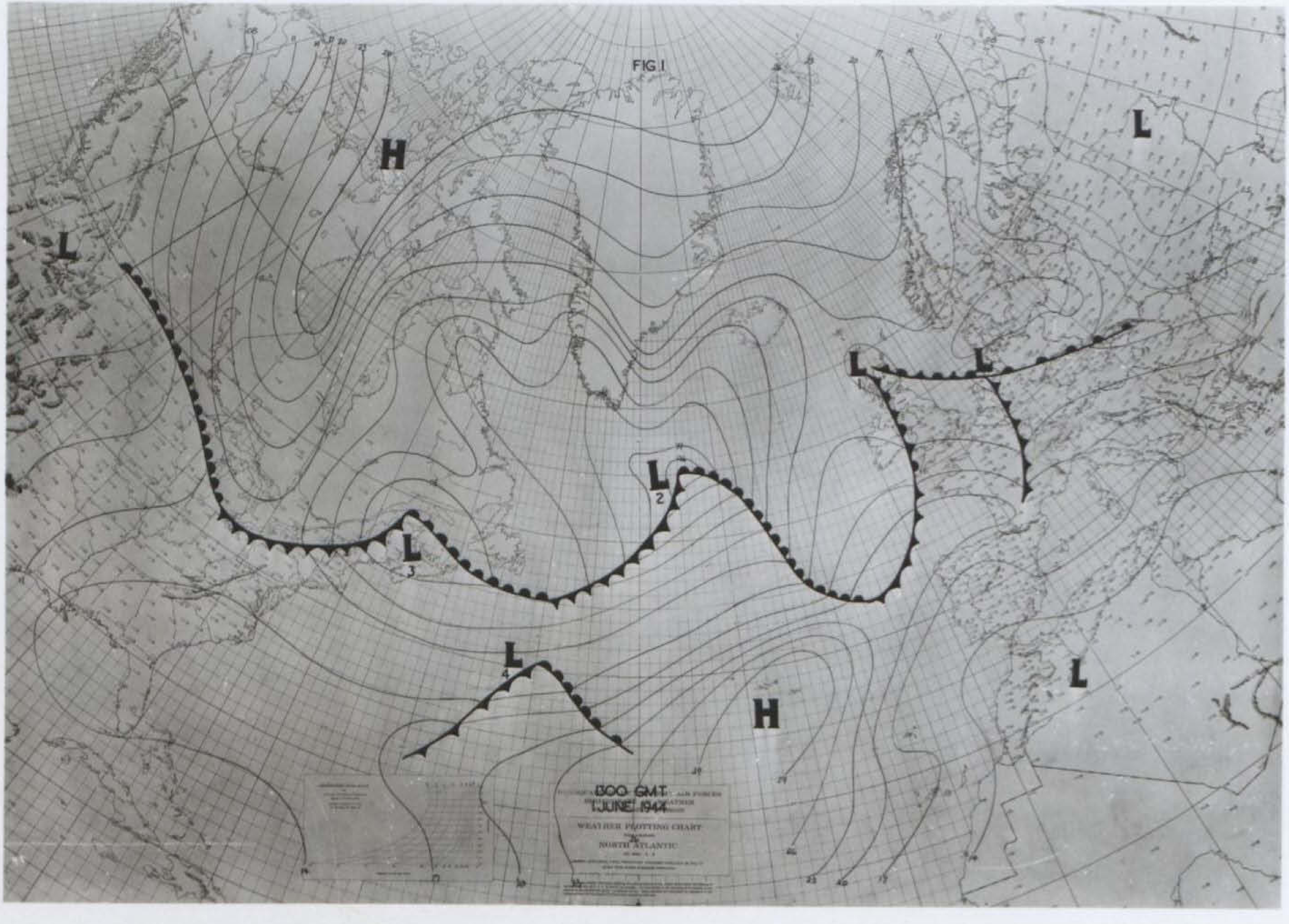
FIG. I
H
L
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L
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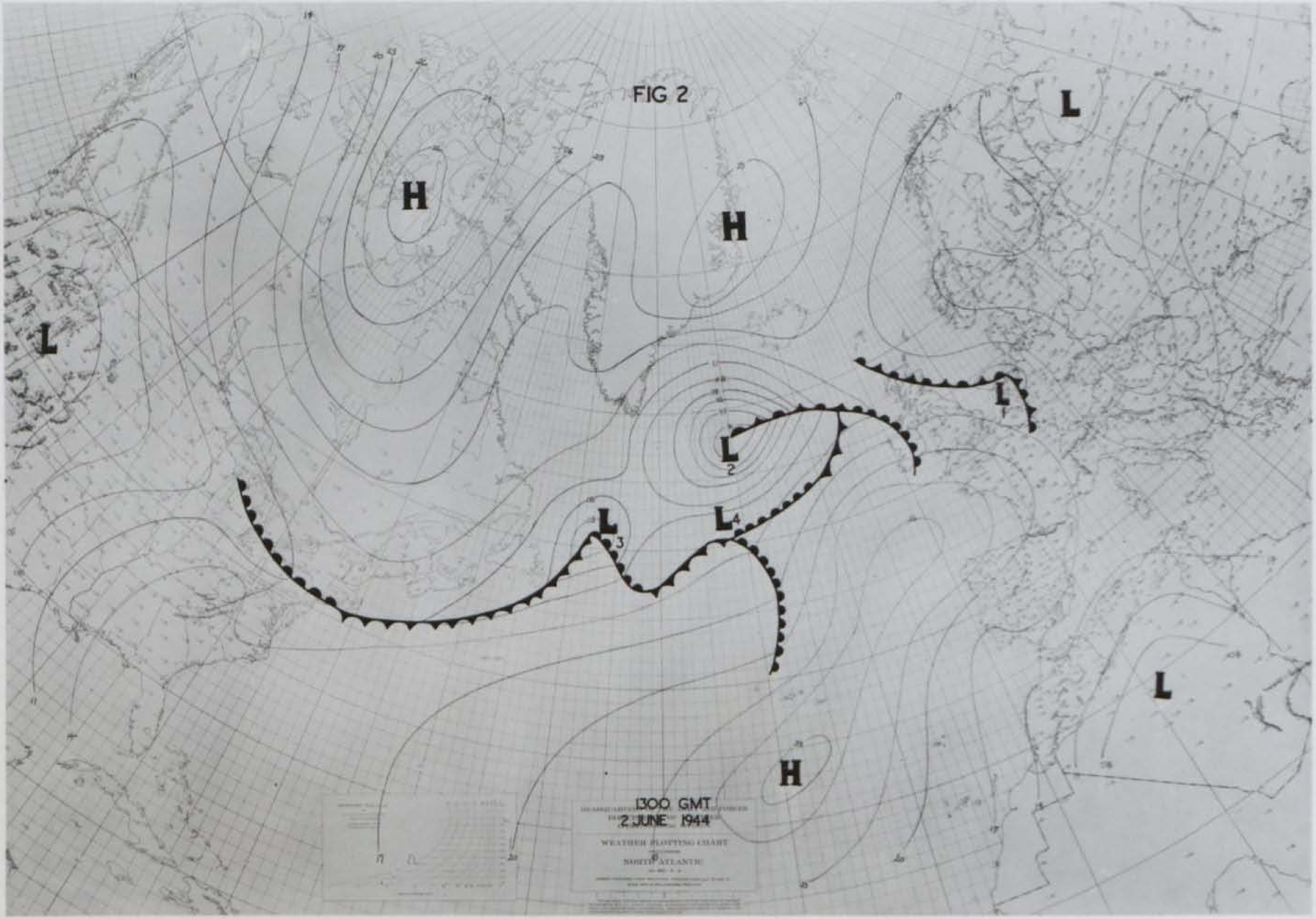
H
1300 GMT
1 JUNE 1944
WEATHER PLOTTING CHART
NORTH ATLANTIC

FIG 2


H
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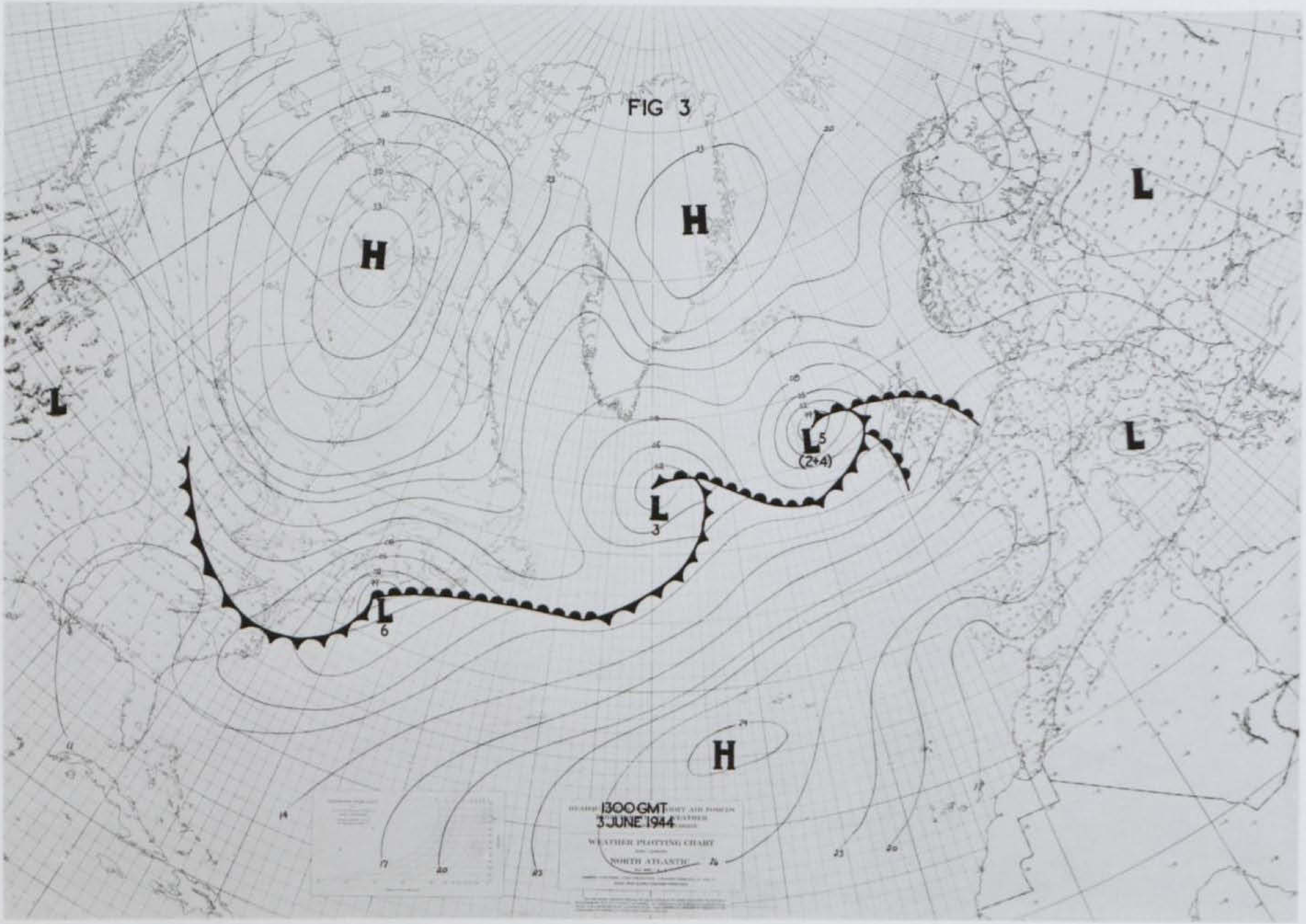
1300 GMT
2 JUNE 1944
WEATHER PLOTTING CHART
NORTH ATLANTIC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1300 GMT
3 JUNE 1944
WEATHER PLOTTING CHART
NORTH ATLANTIC

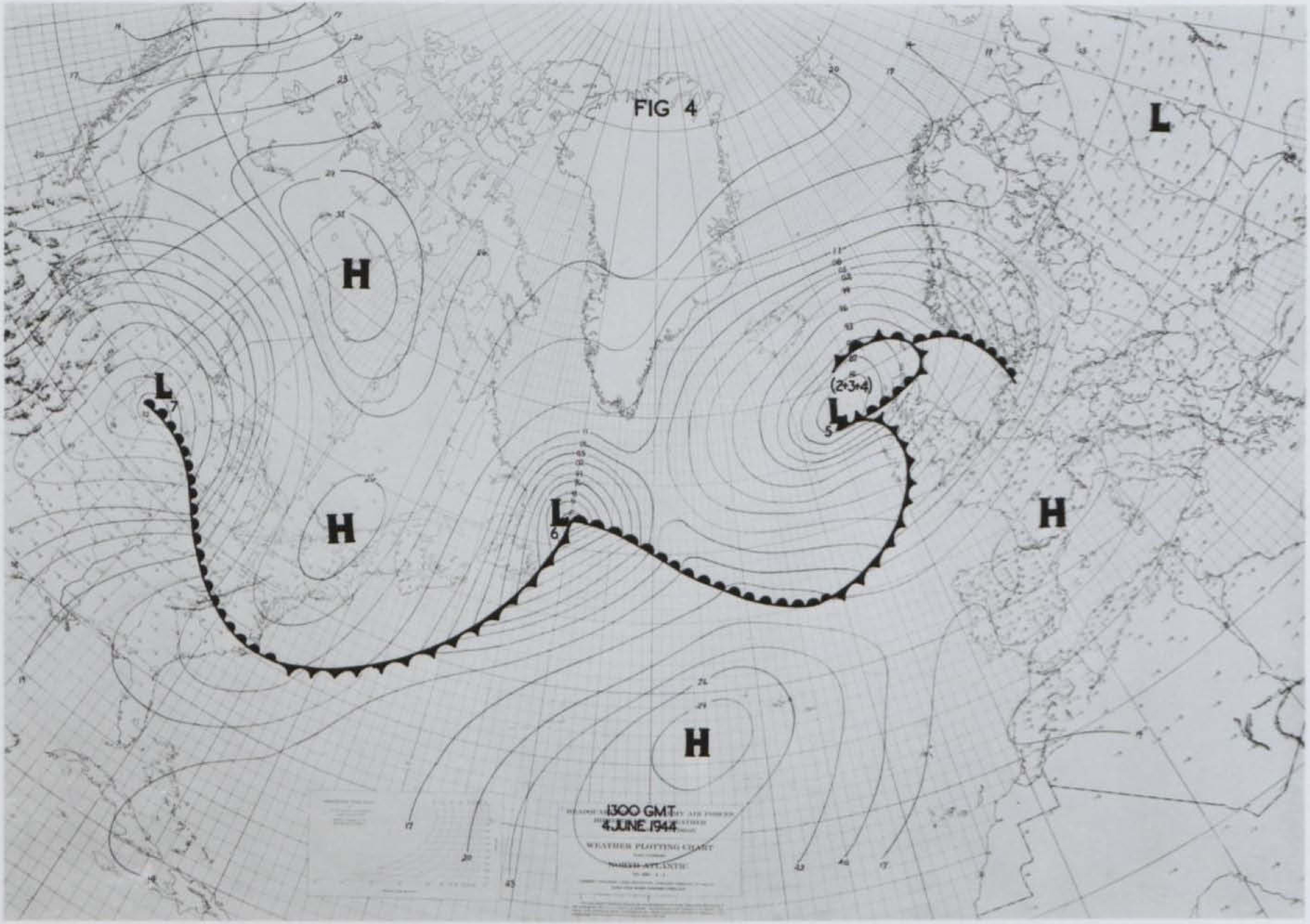
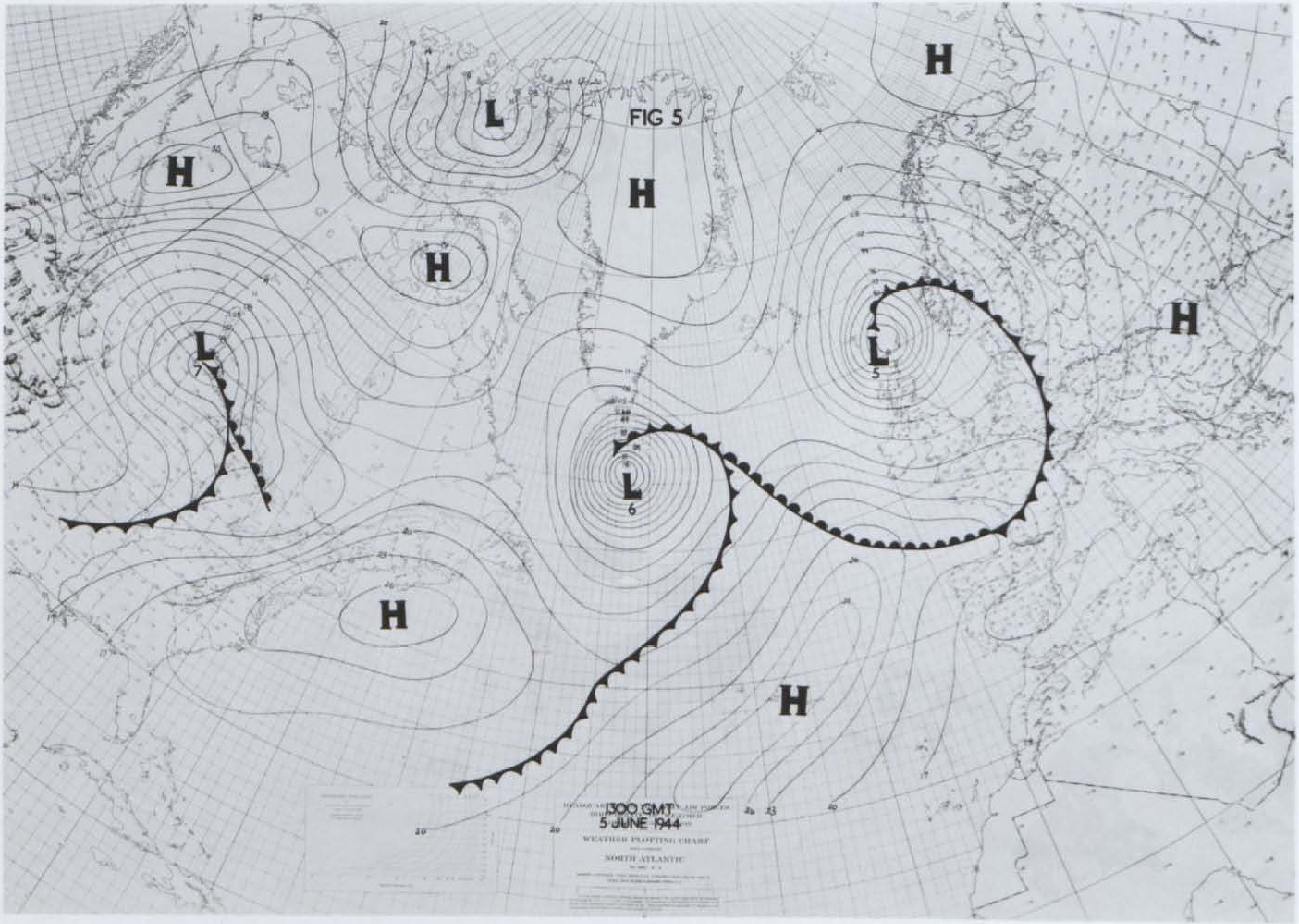


FIG 4
(2+3+4)
1300 GMT
4 JUNE 1944
WEATHER PLOTTING CHART
NORTH ATLANTIC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H
L
1300 GMT
5 JUNE 1944
WEATHER PLOTTING CHART
NORTH ATLANTIC

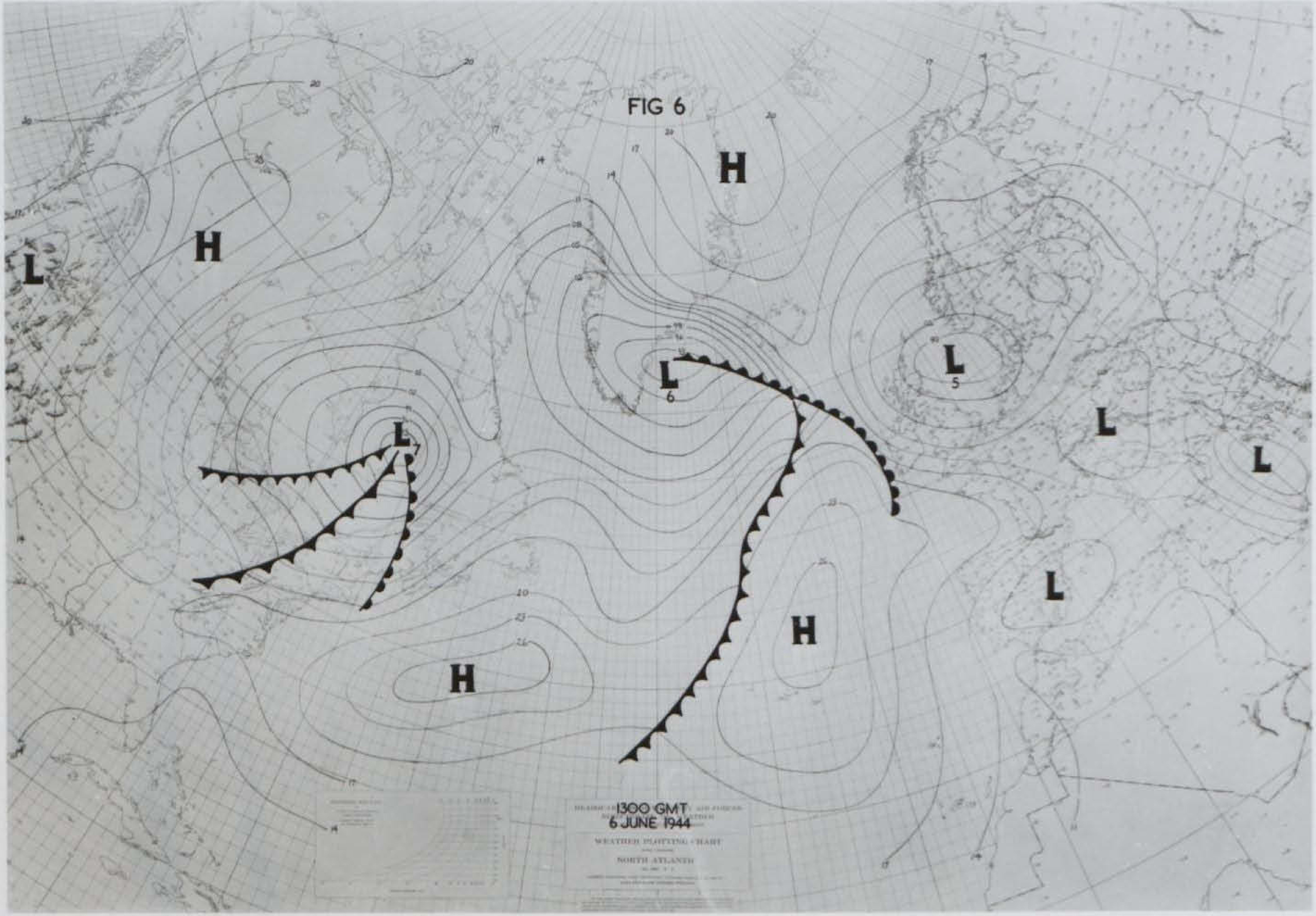
FIG 6
H
L
H
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1300 GMT
6 JUNE 1944
WEATHER PLOTTING CHART
NORTH ATLANTIC

FIG 7

FIG 7
H
H
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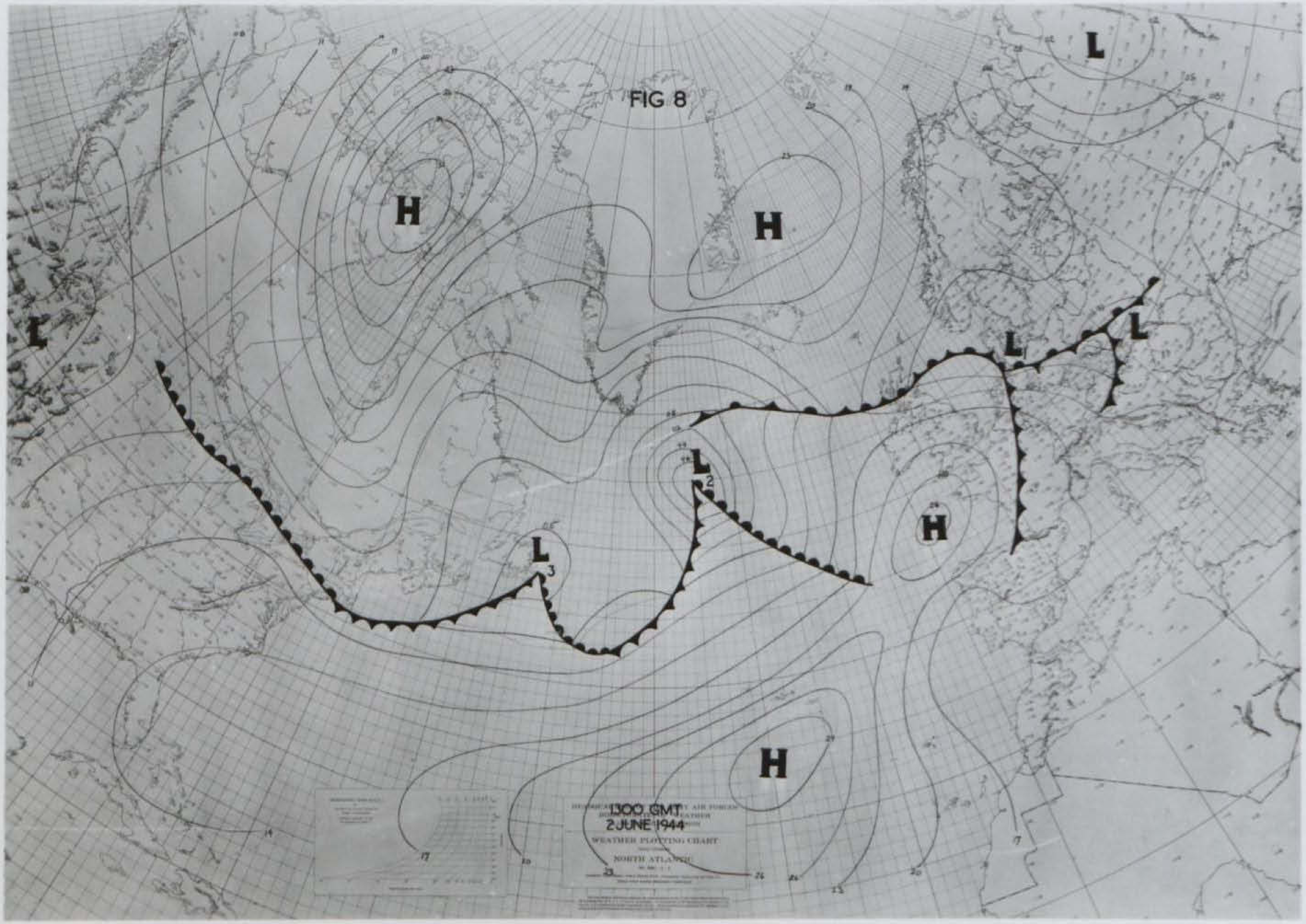
H
0100 3RD
L6
1300 1ST
L3
1300 2ND
1300 1ST
L2
1300 3RD
L4 1300 1ST
0100 GMT
4 JUNE 1944
WEATHER PLOTTING CHART
NORTH ATLANTIC

FIG 8


H
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1300 GMT
2 JUNE 1944
WEATHER PLOTTING CHART
NORTH ATLANTIC

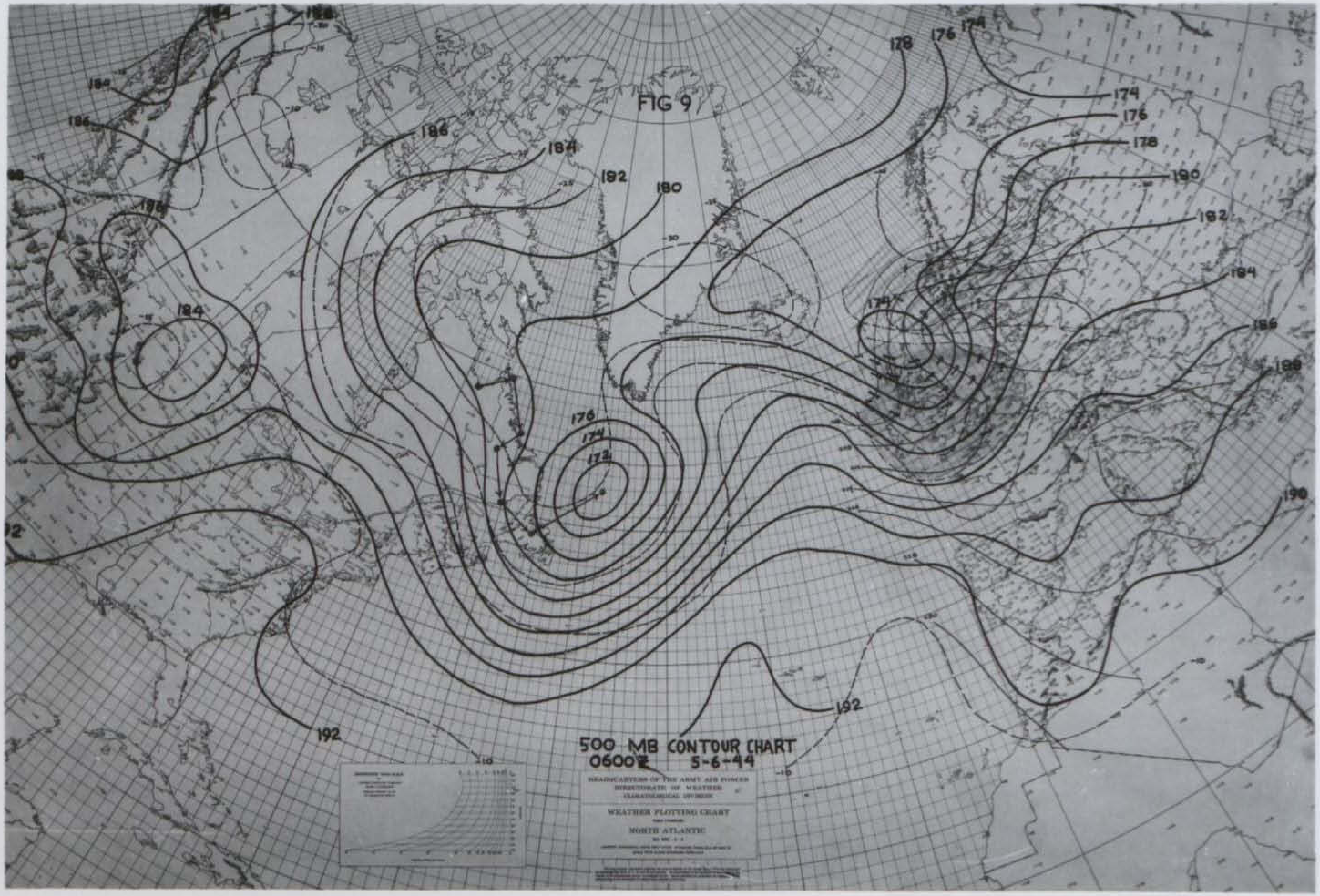
FIG 9
500 MB CONTOUR CHART
0600Z 5-6-44
WEATHER PLOTTING CHART
NORTH ATLANTIC
174
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192

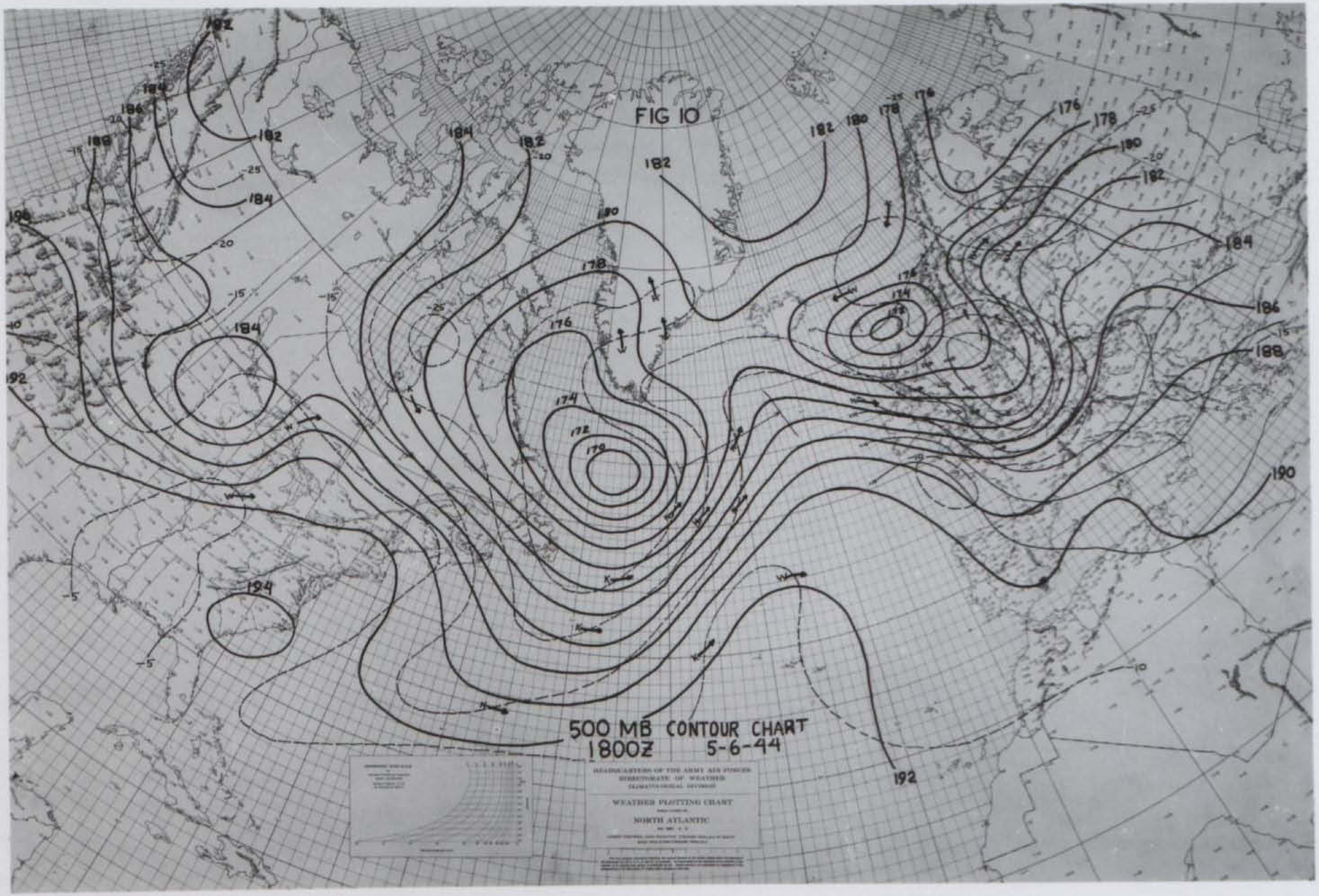
FIG 10
500 MB CONTOUR CHART
1800Z 5-6-44
WEATHER PLOTTING CHART
NORTH ATLANTIC

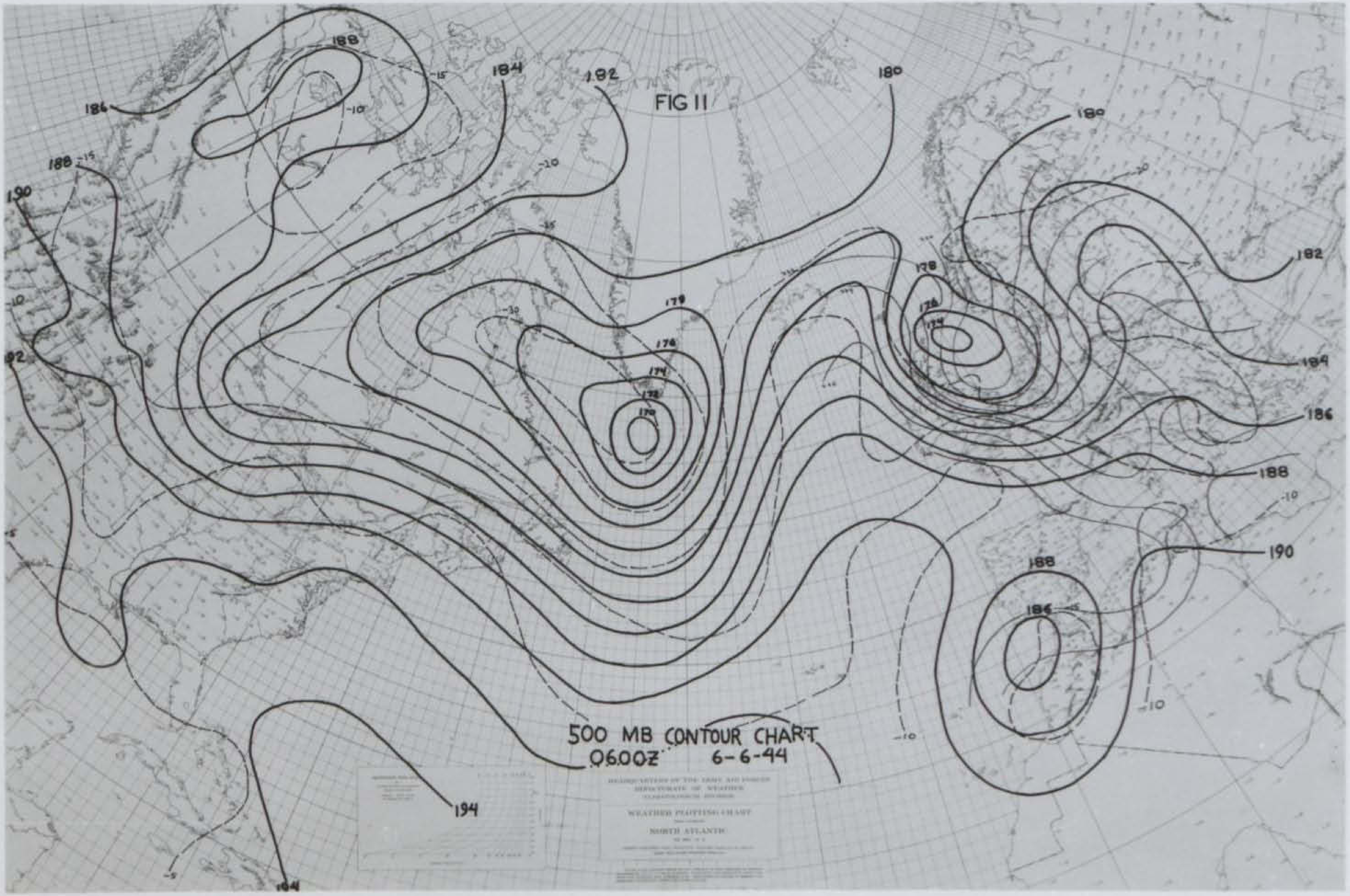
FIG 11
500 MB CONTOUR CHART
0600Z 6-6-44
188
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172
170
194

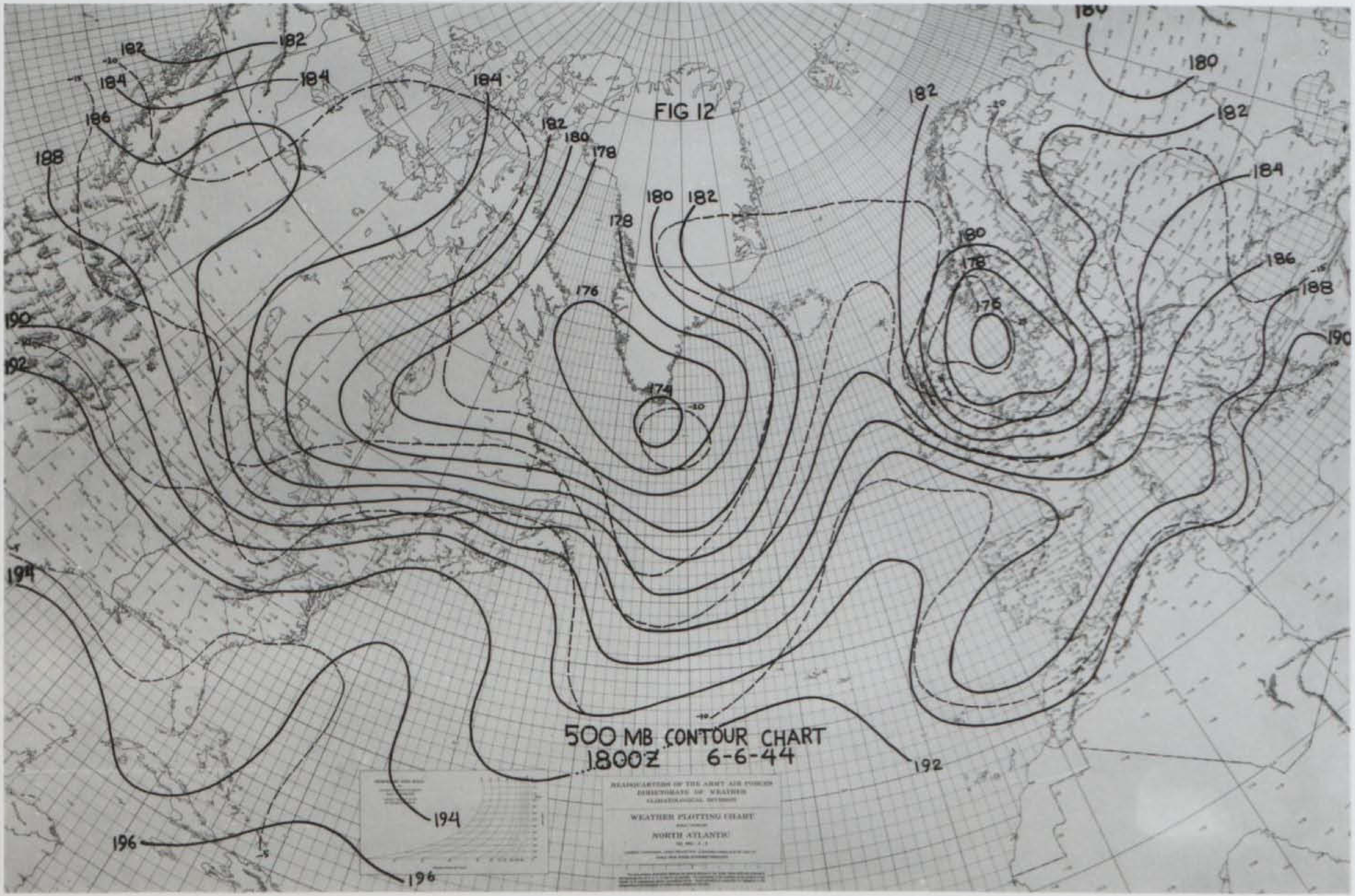

FIG 12

500 MB CONTOUR CHART
1800Z 6-6-44